Government, Science, & International Policy

A COMPILATION OF PAPERS PREPARED FOR THE EIGHTH MEETING OF THE PANEL ON SCIENCE AND TECHNOLOGY

Committee on
Science and Astronautics

U.S. HOUSE OF REPRESENTATIVES

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AND ASTRONAUTICS
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1967

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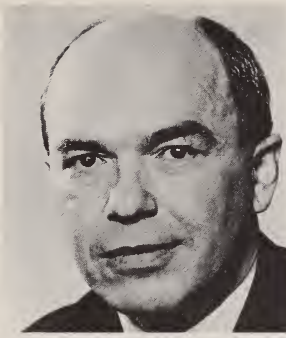

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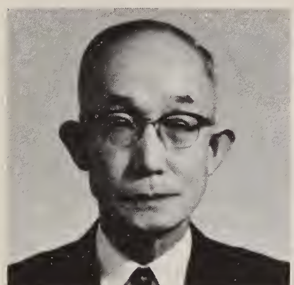

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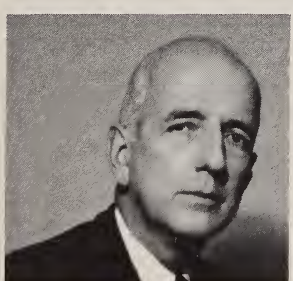

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INTRODUCTION

In January of this year the Committee on Science and Astronautics met in the eighth annual session with its Panel on Science and Technology.

The theme of the conference we deemed to be of unusual and timely importance—Government, Science, and International Policy—and, in fact, it proved to be highly informative and useful to the Committee. We sincerely hope it will be equally valuable to the international scientific community. With the thought in mind that the conference would also be of value to Congress as a whole, we have printed separately the *Proceedings* of the conference and have distributed these to every Member of Congress.

During the course of our 3-day meeting, the Committee and the Panel heard papers given by seven men, both from the United States and from abroad, who are outstanding in the fields of science and administration. In addition, the Committee was fortunate in receiving observations on the meeting from two distinguished visitors. The subsequent demand for a compilation of the papers delivered, and the observations on them, has been great enough to warrant a special printing. Hence this publication. It is our belief that the material and the thinking contained in these papers merits wide distribution. We of the Committee commend them to all persons who, for whatever reason, may be concerned with the relationships and effects between science, government, and international affairs.

GEORGE P. MILLER,
Chairman.

APRIL 1967.

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GOVERNMENT, SCIENCE, AND INTERNATIONAL POLICY

KEYNOTE ADDRESS

The Honorable Dean Rusk

The uncharted region where the interests of science and foreign policy meet is of great import in a world increasingly devoted to understanding and control of our total physical environment. The United States is one of several nations trying to chart that region, and until it is mapped we cannot intelligently choose our routes. In foreign affairs we pool our knowledge of history, politics, economics, science, and technology to arrive at new syntheses.

Science and technology are, in the United States today, a part of the fabric of life itself. We have, in the past 20 years, entered a new phase of the great American adventure. Throughout the world, technology, and the science which supports it, have provided new means of education, new sources of power, new ways of processing data, and fast, reliable transportation and communication. Man is extending his reach beyond this earth and into the vast reaches of space. The new knowledge and concepts, even the very tools of the new technology, promise ever more intensive investigations in the years ahead. We have learned how to pool our resources in coordinated efforts to develop new devices and to exploit new fields. We are supporting science and technology on a scale undreamed of even two decades ago.

We are all familiar with the so-called culture gap between science and the humanities, and more recently with the "technological gap" between the United States and Europe. Last year, Vice President Humphrey said to this committee:

> I think there is danger of another gap—a gap between public policy and advancing science and technology. It is in government that we must face the task of closing that gap. * * * It is only in recent years that we have really understood the close relationship between public policy at the governmental level and science and technology.

In the interest of closing that gap, the Department of State began a program at the Foreign Service Institute, in 1965, designed to equip Foreign Service officers with some competence to handle science as a part of foreign affairs. For the most part, we selected officers who will be assuming the foreign affairs burdens over the next decade. We followed this with a program for the exchange of officers with the scientific agencies to provide direct experience in scientific programs.

We have been holding a series of science briefings and more informal "science luncheons" for high level Department officers. Our last science briefing was on the implications of the worldwide use of nuclear power. The latest science luncheon was held yesterday, and it was my pleasure to host this committee's distinguished guests from abroad. Dr. Hornig, who will speak to you tomorrow, was also our guest at a recent science luncheon,

and our subject was the impact of computers on society. I have found these discussions with eminent men of science to be invaluable.

For any American involved in public affairs today, scientific literacy is a must; and that is particularly so in foreign affairs. We are firmly convinced that the Foreign Service officer should be familiar with the ways, the concepts, and the purposes of science. He should understand the sources of our technological civilization. He should be able to grasp the social and economic implications of current scientific discoveries and engineering accomplishments. I think it is feasible for nonscientists to be, in the phrase of H. G. Wells, "men of science" with real awareness of this aspect of man's advance.

But the burden is not all on one side. Scientists and engineers must, of course, recognize very real progress in many fields outside their own specialties, and they should be conscious of the difference between the values of society and the verifiable truths of the natural sciences. For such men there is a role in the foreign policy process. I think that perhaps scientists have been a little more willing to wade in the turbulent pond of foreign policy, and that we in foreign affairs must be more willing and better prepared to dip in the waters of science. That science is international in character has come to be regarded as a truism, but it is no more true of science than it is of the humanities or the social sciences. The larger truth is that billions must live together successfully on this planet, and that we are making common cause in vast areas of human competence and search for knowledge.

This committee has pioneered in equipping men of public affairs to deal intelligently with policies involving science and technology. As a byproduct of that goal, scientists and philosophers of science have also had their horizons stretched, not only through presence at these seminars—the Committee's reports are widely read. A valuable new channel has been established between public affairs and the scientific community with this Committee at the crossroads.

We have, in the State Department, a small group of scientists and Foreign Service officers working with the science agencies and with the scientific community on policies and programs for international scientific and technical cooperation. We do not administer those programs; but we guide them and retain the foreign policy decisions. The Department's International Scientific and Technological Affairs Bureau has the resources of the Government at its disposal in the United States, and a network of scientific attachés in 17 capitals on the other end. At some major posts, our science agencies support their own representatives to assist in specialized cooperative programs. It is not a question of preparing to move in new dimensions; science and technology are already important elements in our international relations, and indeed, have emerged as instruments of foreign policy.

To some extent, we can extrapolate from politics, economics, and science in projecting future policy. In a way, science is the least predictable of these three major fields. There are few "breakthroughs" in politics and economics; these are evolutionary fields. Broad patterns, such as a United Nations Organization, the rise of nationalism in Africa, and the movement of Europe toward economic integration, are discernible far in advance. To a lesser degree this also holds for the products of known technology. We foresee the wide use of nuclear electric power and satellite communications, and we can predict some of the uses to which computer technology will be put, for example.

However, we cannot foresee the breakthroughs in basic understandings to come. Let me illustrate this point. Thirty years ago, President Roosevelt established a blue ribbon science committee to look into "technological trends and their social implications." The committee was accurate in predicting increased development and use of helicopters and conventional aircraft. Autogiros and dirigibles were reported as on the way out. The committee predicted color television (and commercials), stereo FM radio, our modern highspeed highway system and urban traffic congestion. Air conditioning, plastics, frozen foods, infrared and radio air navigation, microfilm and accounting card machines were also predicted. All of these extrapolations were based upon then-known technology. But where were the microcircuit, the computer, radar and sonics, the jet engine and rocketry, radioactivity, and underwater breathing gases? The top three scientific and technical fields of major foreign policy interest today were almost completely ignored by that eminent committee. Space technology, or even rudimentary investigations of our solar system, were not mentioned. In oceanography mention was made only of the possibility of extracting minerals from sea water. In spite of predicted future needs for oil, none of these experts considered the continental shelves as new sources. Investigation of the sea as a source of fresh water, for fish protein or simply because of man's native curiosity was not considered. The sole references to the third area, nuclear energy, was by a chemist of some vision in these words:

> Much has been said and written about releasing atomic energy and utilizing the vast forces that it represents. While we see no immediate possibility of doing this economically, who shall say that it will not be achieved, and once achieved, how shall we estimate the social implications resulting from the use of such energy?

How indeed? This same man of vision advised that:

> It is the unexpected turn, when some little detail has been perfected after long search, that brings such things to pass, just as occasionally a promising development must be dropped when some unexpected defect develops. These are what make prophecy difficult.

And so they do. The year after that report was written nuclear fission was discovered and, in 4 years more, the world's first nuclear reactor reached criticality in Chicago, opening the nuclear era. In our turn, we cannot now predict if we will harness the thermonuclear reaction nor would we be able to gauge its social and economic implications.

Nevertheless, an occasional look ahead is of great value. Although the President's ad hoc Science Committee back in 1937 did not foresee some major innovations soon to come, it was fairly successful in predicting the future uses of technical devices and methods then known or just coming into use. The value of this type of forecasting to policy judgments is obvious. In most cases a true technological innovation does not reach full bloom for some years—the first basic patent on the transistor was, after all, issued in 1930. Sometimes it may be telegraphed in advance, as are the new energy storage devices, but in these cases the specifications for an end product are set forth in the beginning; it is directed research.

Congressman Daddario recently called for consideration of an early warning system to apprise us of the potential dangers of certain technologies. If this call is heeded, as I hope it is, we can be better prepared to cope with the problems posed by our advancing technology. The system could perhaps even be extended to provide useful forecasts for the foreseeable future. I would think that a distinguished committee, drawn from the natural sciences, the social sciences, and industry, could be impaneled

about every 5 years to explore our technological future. This could satisfy the need for expert opinion on the directions of science and technology so far as it can be foreseen, within acceptable time limits and without a permanent watch dog group. After all, technological forecasting is much more sophisticated than it was in 1937, and we should take advantage of the new techniques.

Although scientific prediction seems to me to remain a chancy business, we can usefully examine some aspects of the changing modern environment which are of direct concern to foreign affairs, many of which can only be dealt with internationally.

The increasing pollution of our atmosphere, particularly in large urban complexes, is of common interest to the advanced nations. The industrialization and urbanization of the developing nations will further contaminate the atmosphere. An international cooperative effort to cure our air, followed by international conventions to keep it clean, would be a long step toward meeting our responsibilities to our own future.

Population pressures can be relieved by means more civilized than war, disease, or famine. Recent discoveries make possible effective population control; and information and assistance for family planning are widely available. The barriers are those of conviction and communication. The governments of the world must first be convinced of the necessity for a program of concerted and immediate action. They must act in time to prevent the mass starvation predicted within the next 15 years. We shall need more food, but more food is not the long-term solution. We must continue development of better instrumentalities for population control; we need better means for reaching billions of people; and we must recognize that a crisis is at hand. Changes in mores are in process in many parts of the world, and the approach is becoming international. In the President's words: "Every member of the world community now bears a direct responsibility to help bring our most basic human account into balance."

The spread of nuclear power reactors requires reliable and credible safeguards over the use of nuclear fuels and equipment, to prevent their diversion to military uses. The further proliferation of nuclear weapons programs not only increases the hazard to peace, but diverts material and human resources from more constructive goals. We have a good beginning on effective international safeguards, but much remains to be done. Some of the remaining tasks are political and some are technical. We must act in good faith and with resolution to try to assure the world that the doorway to nuclear warfare can be locked.

A cooperative assault on the treasure chest of the seas would prevent the waste of talent and money through unnecessary duplication.

The challenges of our space environment require a truly international response. It is already clear that there are benefits to be derived from the use of space which are worldwide in application. The agreement last month on a draft treaty on the peaceful use of outer space makes this a propitious moment to consider again whether we cannot respond even more effectively to this challenge.

All of these possibilities for cooperative programs with other nations call for an advanced technology. But we have not forgotten our own growing pains.

Most of the world's population live in the developing nations, and not all of these are making sufficient material progress. There is an ever-widening gap between the advanced and those struggling to keep their heads above

water. The advanced nations must assist the developing countries in building a base for technological competence. We cannot overlay advanced technology on an insufficient base. That base must first be prepared through intelligent planning toward rational goals.

Our world has acquired a new orientation over the past 20 years. Science and technology are advancing the clock of civilization at an ever-increasing rate. Science has become accustomed to its place at the frontiers of man's knowledge. But we do not forget the older frontier where man meets man, and we welcome the alliance of the natural sciences with the social sciences in meeting new facets of old problems in the world laboratory.

The political significance of strong national programs in science and technology expands steadily. Political-scientific areas such as disarmament, nuclear safeguards, ocean exploitation, space technology and communications, and water management are areas in which the natural and the social sciences meet, and they offer major opportunities for international programs. Wider use of forums, such as this today, to bring the international problems of science and technology before learned men from both broad areas can assist in finding the solutions.

As to our approach to this kind of international cooperation, my points were three. We can make better use of new techniques for technological forecasting as an input to foreign policy judgments. New understandings and mutual respect between the physical sciences and the social sciences are prerequisites if the gap between them is to be completely closed. We must have programs of international scientific and technical cooperation on two levels: with the advanced nations in understanding and controlling the total environment; and with those nations in assisting the material progress of the developing nations.

Our future no longer stands in the wings. Man's needs and his competence have both reached dimensions which can no longer be ignored. The scientific revolution has arrived—live, and in color. We cannot clearly foresee the advances, discoveries and innovations which lie ahead, but the uses to which we put the new knowledge in our human relationships may well be critical.

[illegible]

SCIENCE AND TECHNOLOGY IN LATIN AMERICA

Carlos Chagas

No doubt exists whatsoever about the significance given to science and technology as a fundamental step of development by many people in Latin America, among whom we find the whole of the scientific community and a great number of our more progressive politicians and administrators. They do not constitute, however, a sufficient majority to be really influential, or even to be representative of our economic and political elites.

The origins of this situation are too intricate to be easily explained.

It has been said, for instance, that this state of affairs is the consequence of a narrowminded system of education stemming from a classical and rather conservative way of thinking followed—until very recently—by the religious institutions that had the monopoly of the education of the better-off classes and kept, in that way, a decisive influence in the higher level of education. This will explain why universities remained rather obsolete in their structures and aims, obviously unable to cope with the technological revolution of our days, much less to promote it and to adapt it to the national ecology of our many regions. A vicious unending circular interaction thus formed has left no room for progress. It expresses the fact that an educational system simply reflects the aims of the society that has created it.

I cannot say how true this assumption is.

A second hypothesis that possibly carries more weight comes from the observation of the so-called temporary settler state of mind, which characterized the attitude of the majority of the Iberic colonists, or at least of the more prosperous ones, for whom the American adventure was supposed to last only the time necessary to make their fortune, and enable them to return home as rich men.

This attitude appears to be one of the most obvious reasons for the adoption of the policy of immediate results which dominated our social evolution and which is a handicap to all authentic development that must be based, as we all know, on a continuous and always expanding educational infrastructure.

Be it made clear nevertheless, that one shall not judge too severely the past, or analyze our evolution through the optics of the world's present situation. In fact, even if one states nowadays that the steam engine became really effective only after the application of Carnot's law, industrialization not only preceded scientific discovery in many instances, but was even developed quite independently from it—during the 19th century, and up to the First World War. Industrialization became scientifically conscious only when the population growth brought up competition and made success dependent on improved technology.

During this period, the Latin American world was slowly coming of age, abandoning its exclusive dependency on the "milieu naturel" to enter the machine age. The easiness of life in so many regions rich in natural resources, where agriculture had a high productivity, even if

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labored by ancient methods, helped to create and maintain a rather nonevolutionary social system, adverse to scientific changes. It made nevertheless possible the development of a trend of humanistic thought, resulting from classical studies and the cult of the preceding civilizations and traditions, which may be our best asset to cope with the perils of a two-edged technological civilization, in which man is so much subject to stress and danger.

Throughout the 19th century and up to the First World War, desperate efforts were made by pioneers of scientific research. But because they had to fight the incomprehension of the "milieu," their efforts were almost always ephemerous. Their attempts may impress us today as amateurish, but they represented in fact an extraordinary exertion performed against all kinds of adverse factors.

Those attempts, however small, were a step forward and contributed to the creation of centers of very high quality which were at the time in many cases comparable to those abroad. Mostly centers of medical research, they were almost always established outside the universities, as were their European models. These institutions were created because, at the beginning of the century, the Latin American society had reacted favorably to the challenge from the environment: health had already become a social preoccupation, medical education was encouraged, some important well succeeded prophylactic campaigns, conducted by local authorities, and thus medical research institutions established.

Together with the establishment of geological services, charged with national mineral surveys, and natural sciences museums, an outcome of the expeditions which visited Latin America during the former centuries, these medical institutions formed the embryo from where Latin American scientific and technological basic structure should build.

But let us leave the past, and try to analyse the present, in order to sketch the perspectives of the future, gloomy or hopeful as they may be.

The present situation is rather critical, because a gap increases every day between the Latin American nations and the developed countries.

This is undoubtedly due to the profound unawareness of Latin American elites to the fact that the First World War changed the prospects of civilization by introducing into it science and technology as a new instrument of social progress. It is certainly this point that the rhetoric education of the ruling generation became a stumbling block in the march of progress.

No policy was adopted, and except for a few and isolated men—classified as rebels—no one suggested the need or tried to introduce substantial changes in the educational, scientific, and technological fields.

Two facts, however, are clearly observable from the period which ended around the late twenties. First, one sees that scientific research had no relationships with technology, and that, except in the field of medical research, very little demand for local technological developments was made. Secondly, if there was an enormous difference in quantity between the scientific institutions of the advanced countries and the Latin American ones, and even in the investment devoted to scientific education, as small as it may have been in the more civilized world, the quality of scientific achievements in Latin America was not so much out of pace as may seem.

When did the loss of pace occur, then? Probably in the thirties—when the revolution of the triodes and the pentodes took its full swing—and the gap started which has increased ever since, slowly at first, and very apprehensively in recent years.

Little has been done since at the national level to overcome it, and the recent prevision of an unbalance between the developing countries themselves may increase the pessimism already pervading in our countries a danger by itself to the preservation of our present social system. National efforts are again quite solely made by isolated men, and praise should be bestowed upon Bernard Houssay, from Argentina one of the very first to fight brilliantly and correctly for the recognition of the right place that should be given to research in Latin American Universities. His efforts, like those of many pioneers, encouraged many of us and are a starting point of a spreading interest for science and its implications.

One must not forego the impulse and incitement given to the Latin American scientific world from the thirties on by the Rockefeller Foundation. Not given to improper praise, I wish to substantiate this assertion with a concrete example: from the podium of the inaugural session of the 21st meeting of the Brazilian Association for the Advancement of Science, held in July 1965 in the city of Belo Horizonte, and attended by a thousand participants, I had the opportunity to scrutinize the audience. It was clear that practically all the leading groups present had been supported, at a certain phase of their evolution, by the Rockefeller Foundation. The scouting system pursued by the institution, and admirably conducted by Dr. H. H. Miller Jr.,—dear to all Latin American scientists—under the general guidance of Warren Weawer, is an extraordinary example of a successful venture. The policy then followed by the Rockefeller Foundation was the best impulse Latin American research has ever received. It formed groups, whose expanding influence has been of great importance, who created around them a climate of expectation and hope, which prevails and may counteract the feeling of anxiety and frustration still prevalent in our scientific and technological communities.

It is a rather difficult task that of analysing Latin America's scientific and technological development. At this stage, I would like only to point out the major problem that hinders it.

It seems fundamental and difficult to eradicate the appalling lack of information on science and technology of the ruling classes, how they develop so that their role in modern society can be fulfilled. Is this the result of the rhetorical conservatism of the previous higher educational system, together with other factors as, in Brazil for instance, the vagaries of a few obstinate followers of Auguste Comte, who influenced so much the early days of the Republic? Is it due to a prolongation of that spirit of profitable exploitation which dominated the minds of the first settlers? The answer may not be possible. A fact, however, is certain; planning is still a novelty and the strategy of development has been based in one reality; ad hoc industrialization. In consequence, all technological progress took the form of small leaps, many times sterile, because unsupported as they were, by progress based on education, science and applied research, which is the mark of our time.

It is evident that this misinformation led to a lack of planification in the development of science and technology.

Some activities in the international field have been carried on in order to help and stimulate national activities and even to supplement them.

They have never received the correct answer. In 1947, for instance, UNESCO held the first Latin American Conference on Science in Montevideo. A chart was then approved, but very few Governments gave it the importance it deserved. In 1959, the Organization of American States called for a meeting of scientists, as individuals. This was held in Wash-

ington, and to our chagrin, pointed out that little progress had been made, and showed also the diversity of conditions existing at the moment in Latin America, where some countries still debated fundamental ideas already fully accepted in others, such as the need for a full-time regime for scientific and technological workers or specialists. The scientific department of the OAS has not received as yet the encouragement member States should give, and its activity has been forced into the background of the whole organizational action.

In 1962, a task force of the OAS was again called upon to produce a paper that would serve as a guide for the Alliance for Progress. This meeting, held in February 1962, showed again different perspectives between countries of the region, but mostly between the various participating specialists, administrators, economists, scientists themselves.

UNESCO, in 1965 again, sponsored a large meeting held in Santiago, under the title of "Conference for the Application of Science and Technology to Latin America," and more recently, a smaller meeting of the heads of existing research councils, together with prominent Latin American scientists, in Buenos Aires.

Many of those meetings, however, were in part a failure, either because the governments were not represented by the right individuals or did accept the conclusion reached, or because the scientists present were skeptic about the purposes and achievements of such gatherings and, afraid of receiving no strong support after their return, did not participate wholeheartedly in them.

Finally, before coming to the second part of this report, I would like to tackle a question that has great implications in further developments of science and technology in Latin America. This is the instinctive distrust many of the most eminent specialists in the region feel in regard to government initiatives in the fields of scientific and technological planning. This is caused, on one hand, by the feeling of despondency they have experienced many times when in touch with the irregularity, and the procrastination of official measures, and on the other hand, by the irritation subconsciously felt when facing the patronizing self-assurance of younger economists brashly planning in the scientific and technological fields.

Let us now face the perspectives of scientific and technological development in Latin America. I shall start by enforcing strongly the assumption that research is the basis of technology, and thus of development. I believe that this need not be dwelt upon.

The lesson from the Geneva Conference for the Application of Science and Technology to Developing Regions, held in February 1963, is of value. There, defendants of my thesis, and of the opposite one, which deems that the importation of technology leads directly to development, were present. The unexciting results of the Development Decade of the United Nations, up to now, in the field covered by the Geneva Conference, may be attributed partly at least, to the emphasis given to this second tendency, and the orientation taken since by the increased multilateral or bilateral aid.

This tendency contrasts, on the other hand, with the consensus reached at the same Conference, by which it was admitted that the transfer of technology without adaptation is profitless. This demands unequivocally for a building up of autochthon knowledge. The philosophy of development under these terms was admirably defined by René Maheu, UNESCO's Director General, some time after Geneva. He expressed it by stating that: "The development of a nation cannot be achieved if science and

technology do not cease to be an imported magic, to become a custom of its people." This statement points immediately to the importance of scientific education in any program for scientific and technological development of developing regions, for how can these activities be patronized by a nonalerted society? This conception was fully recognized recently by the 14th General Conference of UNESCO, November 1966, which recommended the execution of a concerted program of scientific education in a world scale, as the most direct operational contribution this international agency could give to the development of less developed areas.

Before entering or amplifying the discussion on the subject of education, let us see, however, how a policy of scientific and technological development can be conceived. There is no doubt that it must be shaped in two forms. One, the more significant, is of a long-range effect, while the other is directed to produce immediate results.

The first one has to be developed along the three following lines:

(*a*) the increase of scientific education on all levels, and the establishment of technical schools on the intermediate levels;

(*b*) the creation of a real infrastructure including:

(1) the creation of universities or their improvement in regard to research and graduate teaching;

(2) the establishment of technological institutions; and

(3) the organization of cooperative and planning governmental bodies, like research councils, and eventually ministries;

(*c*) the spreading of scientific information to the mass, taking in due account the future administrators and candidates to civil service, as well as the agencies responsible for mass communication.

The short-termed one must foresee the importation of advanced technology, which needs a minimum of adaptation, capable of being productive with the limited indigenous potentialities and international aid, and of solving problems of immediate and strong economic value or local significance, such as the technology of food preservation, or that of nonconventional sources of energy.

Let us now analyze the long-range policies in a more detailed form. The need to introduce scientific education in all three levels, i.e., primary, secondary and undergraduate, need not be fully discussed; let us study only a few of its aspects.

The one related to the primary level may be analyzed in two ways. The adequate introduction of science in the primary school represents first of all the modeling of thought indispensable to the establishment of what may be called a scientific humanism, closely related to the "humanism of development," an expression coined by René Maheu. It will be the best weapon to establish the scientific consciousness needed by the modern world. Secondly, it may have in many forms an important bearing on bringing the adult illiterate population to a better understanding of measures indispensable to its social progress, as for instance hygienic precepts. A pilot project held in São Paulo, Brazil, these last years, has shown the good prospects of such an initiative to this end.

The only point I wish to make in regard to secondary education deals with its cost. It is believed by many that it is unbearable to developing countries. Another experiment, done also in São Paulo in a cooperative project of UNESCO and the Instituto Brasileiro de Educação, Ciência e Cultura (the Brazilian National Commission for UNESCO, São Paulo quarters) under the leadership of Dr. Baez from UNESCO, and Prof.

Isaias Raw, from USP, has shown unequivocally the delusion of such a concept. It is not costly when the modern approach, including the change of curriculums, is taken into consideration. To this end, what needs to be provided for scientific education in less developed countries, are centers for experimental study and renewal of scientific education, taking into consideration the elaboration of new and adequate curriculums, the preparation of modern teaching techniques and materials—including instruments, audiovisual processes and textbooks—and an autoreproducible system for recycling teachers. As pointed by many authorities, this should be done under the responsibility of universities that are supposedly in contact with new ideas and familiar with research.

These proposed centers far from limiting their action to the scientific field which would be their first beneficiary as innovation is more apt to foment in it, will influence all fields of education, thus allowing for the forward jump that the educational system of developing countries has to master, a jump which cannot succeed by use of the classical springboard, and which is more necessary every day, as the pressure of an ever-increasing young population becomes more pungent.

Much should be said about the scientific teaching on the undergraduate level.

It presents in Latin America unquestionably a much better promise than the other two, as practically all "centers of excellence" in this region are now located in the more progressive universities.

This brings us to the problem of the scientific and technological infrastructure, of which universities are one of the major parts.

The establishment and reinforcement of scientific basic structures is one of many very urgent measures to be taken.

I would like to confine myself, from now on, to the region I come from.

Let us deal first with the university problem. Our first perplexity comes from the evidence that the contribution of universities to scientific and technological development has been rather scanty, not to say void. It comes maybe because, encircled in a rigid structure, wherein flexibility and adaptability are impossible, Latin American universities were unable to give more, and for this reason have been subject to strong criticism, and the prey to political and demagogical pressures. It is plain, however, that in more recent years, a university reformation—not to speak of a renaissance—is looming. It is the working of a younger generation, mainly trained abroad, aghast with the conservatism of the present system, and in conflict with the old tenets of university authority. This movement has to be strongly supported. The concept it involves centers around some points which should be briefly expounded.

The old structure of separated, dominant professional schools has to give way to a new one, in which the core of the institution will consist on basic institutes for sciences and for classical studies.

This may permit, among others, a change from the present situation, in which the teaching facilities and laboratories are closed for the greater part of the time, to a new one, where students will rotate in their utilization. The permanency of isolated chairs, under the control of a single full professorship, should be abolished, and substituted by the departmental system in which the various disciplines can evolve under the active responsibility of younger teachers thus able to reach a leadership position in the prime of their creative age.

This reformulation of the university problem has to take also in consideration the need of a thorough modification of the management proper of the institution, put it in a more objective form, and adapt to it the modern forms of the principles of administration.

A new policy, that of the "numerus adequatus," should replace that of the "numerus clausus," prevailing in Brazil and some other Latin American countries, and the nefarious one of unlimited acceptance still carried by the majority of universities.

On the other hand, a system of intercommunication between society as a whole and the universities must be established. In other words the preoccupations of the universities should concentrate on the problems which surround them.

One has to stress, however, that no modification of the system may be effective, unless all universities adopt in an unlimited way the full-time regime.

But, let us repeat it, unless a fundamental change is introduced in our university system, it will be unable to cope with the two most fundamental problems it faces: one, the increased number of young people arriving at the age where they receive higher education; the other, the necessity to establish or include in its system a flexibility component, able, by its activity, to allow for the adoption of a prospective point of view, capable of the changes which have to be considered, when one scrutinizes the evolutionary dynamics of our present world.

TABLE I.—*Population under 20 years*

	Argentina	Brazil	Chile	Colombia	Mexico	Venezuela
Year	1960	1960	1960	1963	1960	1965
Percent	38.7	52.7	49.4	50.4	54.4	55.3
Students	8,656,000	36,972,924	36,473,325	7,614,940	18,987,372	4,823,181

TABLE II.—*Graduates: Distribution by field of study*

	Year	Total	Sciences		Engineering		Agriculture	
			Number	Percent	Number	Percent	Number	Percent
Argentina	1957	8,071	524	6.5	1,080	13.4	173	2.1
	1963	13,626	833	6.1	1,227	9.0	202	1.4
Brazil	1957	14,965	399	2.7	1,172	7.8	398	2.6
	1963	18,487	707	4.7	1,965	13.1	649	3.5
Chile	1957	1,413	81	5.7	231	16.3	29	2.1
	1963	2,712	95	3.5	292	11.0	177	6.5
Colombia	1957	1,747	90	5.1	161	9.2	31	1.7
	1963	3,238	186	5.7	659	20.4	115	3.5
Venezuela	1957	860	14	1.6	121	14.0	22	2.6
	1963	2,942	40	1.4	267	9.1	77	2.6
France	1957	19,216	3,009	15.7	5,941	20.5	530	2.7
	1962	70,919	[1] 20,760	29.2	6,211	8.8	599	.8
United Kingdom	1957	49,367	6,698	13.6	12,832	25.9	604	1.2
	1962	67,282	10,719	12.2	17,890	26.6	666	1.0
U.S.S.R	1957	290,800					30,800	11.7
	1963	354,000					34,100	9.6
United States	1957	440,304	48,376	11.0	41,767	9.5	8,751	1.9
	1963	614,184	74,933	12.0	47,923	7.7	8,920	1.6

[1] The change in science graduates is attributed to the creation of the "3d degree."

Regarding enrollment, one may say that the situation has not reached a more pathetic climax, because of the quantitative deficiency of secondary education. The fact to be faced, clearly shown in all surveys, is that many

more students must be received by all universities, particularly in the scientific and technological domain, if one wishes really to create the necessary manpower capable to overcome the main obstacle which hinders scientific and technological development in Latin America. If one considers that this substantial increase in numbers has to be achieved without the loss of quality, that is, that it has to deal not only with quantity so dear to some administrators, but on the substance of the teaching process itself, one may easily foresee the magnitude of the task that challenges our universities.

Let us now deal with the second aspect of the scientific organization of the less-developed countries, that is, the creation of institutes for science and technology.

Some words have to be said about basic and applied science in developing countries. One may, for this purpose, distinguish three types of research which are the following:

(*a*) fundamental scientific research;

(*b*) fundamental scientific research directly linked to applied science; to be called simply basic scientific research, or linked fundamental scientific research; and

(*c*) technological research, including operational research.

Fundamental research, notwithstanding its baconian character, is an adventure of the spirit, in which the search of new discoveries, or the opening of new fields beyond the horizon of our present knowledge, is the objective. Category "c" has a direct output which can be measured in quantitative economic terms. Basic research of type "b" cannot be evaluated in such precise terms.

It is important, however, to affirm that, as much as technological research is dependent on basic research, it is also dependent on fundamental research. Any attempt to separate them may have disastrous consequences.

May I state, incidentally, that work in the field of fundamental research may still be valid in more modest conditions, whereas the other two need more of the paraphernalia of modern laboratories. The policy to be followed may be sketched as follows: Fundamental research has to be developed at the universities, basic research can and should be developed both at the universities and special institutes, whilst technological research, however, should be developed in those specialized institutions, whose patterns must be in constant evolution, under the challenge of social, economic, and ecological changes. It must be stated emphatically, however, that the beneficial effects of technological research can last only if the country has managed a logistic background, through the first two types of research. To justify partly this assertion, I would like to add that scientific education is obtained only when the student has become familiar with basic research, and that this first training phase is needed essentially in any kind of rational technological specialization.

The general planning policy has to be quite different for every one of these three types of research, and as I have expressed myself on another occasion, in relation to fundamental research, the interference of planning should be limited to the establishment of the conditions necessary for the creative effort it implies, and the work should unfold in great freedom.

On the second type, planning has to go further and determine certain priorities which are in direct relation with the technological research most needed. In relation to this last one, planning has to establish a goal, has to get the machinery necessary for a frequent evaluation of the results as much as to determine the measures for strengthening the evolution of each program.

Governments should have a direct contact with specialized institutes, where applied research should mostly be undertaken, as they are meant to be a strong weapon for development.

However, the official interference must always leave a certain amount of administrative freedom. In the system of mixed economy gradually prevailing in Latin America, these specialized institutes must also be responsible for establishing standards of production. Their existence, however, cannot become a reality unless a great effort already mentioned in relation to scientific education is made. Let us warn also that their establishment must not be the cause of any pressure against the full development of the fundamental research system in the universities, with which, on the contrary, it should be strongly linked. These institutions should also keep a high academic level, and in some cases, develop their own facilities for the basic research connected with their most direct purpose. A recently proposed suggestion to organize these institutions as low-profit societies financed and directed by governments and private industries, presents a realistic perspective which should be pursued.

Notedly, governments have to introduce in their administration, and in a high level, a scientific and technological planning body, such as a research council, and support it heavily. The influence of such a council in Brazil and Argentina, for instance, where they have been established quite early, was surprisingly strong. In view of this experience, we think that besides their status as a direct consultant body to the Government, they must also be responsible for compulsory tasks in a more direct line of action. They will be called upon to stimulate research at universities, to establish a rationale for long-range and intensive training abroad, to formulate the policy of reequipment, to foment closer ties between institutions in the various departments. These councils should be intended to provide exceptional measures to foster research, as for instance the ones which may induce emigrated talents back to their own countries, to open new fields of science and technology, to channel information from abroad, and to create central systems of biographical documentation and diffusion thus allowing for a comprehensive updating of knowledge. They may indicate the need for the opening of the above-mentioned specialized institutions when necessary, and under favorable conditions, to provide for their transference for more appropriate authorities, as well as many other tasks. This rather long description of a national research council role does not portray, however, the extraordinary impact it may have on the scientific community and on the general public as well: its greatest significance in Latin America has still to be emphasized: it is to make the voice of science and technology heard on the highest level of officialdom.

This need has pushed many scientists in Latin America to favor the creation of ministries of science and technology in substitution of research councils. In reality, if the research council board does not have a straight access to the highest decisionmaking body, in each country, then this last solution is the most favorable, though subject to many restrictions: one being that the ministry should have special characteristics, not be burdened by bureaucratic services, and exempt, as much as possible, from operational tasks.

This position can easily be understood if one considers that most of the scientific and technological programs possess a multidisciplinary character, including, most of the time, a need for strong support on the part of social science, so that when undertaken under the responsibility of one single

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governmental department, they will always unfold their work in close cooperation with various others. This coordinating function also belongs to the research councils or to the ministry of science and technology.

The acceptance of many operational duties by ministries of science and technology would evolve into an undesirable centralization, and may deviate them from their principal goal which is, together with their coordinating activity, the planning, in a prospective way, of the scientific and technological development of the country.

Some countries in Latin America have also created national atomic energy commissions. Their impact, in many aspects, it must be said, has been favorable, but only when they have followed a broad general policy. Then they have had a stirring effect on physics and chemistry, biophysics, technology, clinical medicine and agriculture, as much as in local industrial development.

This is a field, however, in which cooperation and planning, on a regional basis, which has not been done, turns out to be a "must" in spite of the political problems that always involve nuclear energy.

The third point in the sketched planification, deals with the need to eradicate what may be called "scientific illiteracy." A vast program of scientific information should be developed in Latin America, so that a better informed public may exert pressure in favor of support for science and technology, and administrators and policymakers may be more enlightened about the real value of science and technology in modern social development.

Many measures could be indicated to this end, and among them one of the most important and urgent is, as far as I know, the introduction of science information courses in the schools of journalism, which are being created or multiplied in the various countries. The importance of this task should not be minimized, because much of the fulfillment of any development prospect will, in fact, depend on its success.

From these outlines on science and technology in Latin America, we may gather some ideas that will help to reduce—or maybe even to abolish—the gap that exists between the developed and the developing countries.

If one tries to allocate priorities, the educational problem appears again, without any conceivable doubt, to be the most important. It has already been said that this is the common factor to all developing countries. Again, one has to consider long-range programs, encompassing the scientific educational changes already suggested. To this end the establishment of the proposed centers for science teaching are to be encouraged as much as possible.

The more immediate program has to concentrate on training, at the graduate level, and in a rapid increase of the intermediate technical education—efforts such as those developed by the Ford Foundation should be encouraged or proposed. It must utilize the facilities already in existence, and put them to work on a regional basis. The policy to be followed may be different, in the scientific or in the technological domain, as it may vary from one topic to the other within these fields. It must, however, embrace a large spectrum of activities from courses and laboratory sojourns of very short duration, to the programing of graduate studies of a much longer duration. In any case, extensive use should be made of the "centers of excellence" already existing. This means that such centers should receive more national as well as international aid.

The greatest difficulty in this case has been many times pointed out in discussions, as being that of the salary scale necessary to keep the center's staff in place, though this problem has been somehow overstated.

One may say that the salary problem is of importance in the brain-drain of Latin America, mostly when no adequate working facilities are provided. In the technological field, an aspect of brain migration unsufficiently exposed is that of the absorption by private enterprise of talents partly or totally taken away from the education or research system. Emphasis must be given to the establishment at the centers of a dynamic system of communication that will keep them in close contact with the scientific and technological centers of the advanced countries. The salary question—that is competition with the international market—may be solved if these specialized institutes are organized, as proposed recently, as nonprofit organizations with the participation of private industries.

The advantage of training in regional centers are various, and only a few will be mentioned here. The training will at once establish a close relationship between Latin American scientists and technologists, which does not exist, and is an essential part of the integration of the region.

Secondly, it will enable them to treat jointly the problems they have in common, and local experience to be more easily transmitted or acquired. It will also allow for a pretraining stage before a sojourn abroad, which means necessarily a more realistic and efficient policy, which has already been put in practice with advantages in some countries.

The training centers should also serve before the launching of more ambitious programs, to be established in special institutions, as teaching centers for intermediate technical preparation.

This part of the planning should be heavily supported by international aid. To be effective, however, it should receive a national counterpart. This should consist, on one hand, of administrative changes established in order to insure the full activity of the "centers of excellence," which need authority, freedom of action within its program, and liberty from the heavy burden of the bureaucratic entanglements which so often have paralyzed Latin America's science and technology.

Again, international aid will make sense only if national governments create working conditions for the trained specialists. This is particularly significant also for the scientific-artisan-training. Unless a young apprentice knows that a career is open to him after graduation, no enrollment for technical courses will exist.

As the scientific training centers will be mostly located at the universities, the improvement of their status will reflect significantly in those institutions themselves. The research activity of these centers can be enhanced in various ways, and very efficiently, as a matter of fact. Such are, for instance, the series of small colloquia—where Latin Americans from all regions take part—organized by the Biology Division of the Oak Ridge Laboratories, and which have been very significant. Together with the recent "workshop" organized by the International Brain Research Organization, held in Santiago last November, it seems that this type of international help may establish a pattern for a good system of keeping the Latin American scientists in touch with the developments of new ideas and new techniques. This has been organized solely, to my knowledge, in the field of fundamental research. There is no reason why it should not be extended to the fields of basic research and technology.

There is another point, however, which must be attacked very urgently and very actively. It is the need to increase the scientific teachers staff in the universities, in proportion with the unavoidable and unescapable

growth of enrollment. Here again, international aid can be of unsurpassed importance by helping to launch a vast program to this end. The counterpart from the governments should be emphasized: it will be to choose between the varying priorities those more suitable to technological fields, to establish standards required for technicians and teaching staffs, and assure them a position such that will enable them, after their training abroad, to proceed with teaching and researching in fairly good conditions.

It seems that it would be better not to use, in the realm of scientific education, the word priority at all. It may be useful to admit to a degree an optional slant toward the need for establishing the proper basis for technological progress, already in the last stages of basic, scientific education.

In the postgraduate level, however, where the "centers of excellence" exist, the problems of priority have a twofold aspect. In the field of fundamental science, efforts should be concentrated on leaders, to whom full authority should be given. Whenever they do not exist in a particularly important field, attention must be concentrated on the obtention of the incoming of international specialists.

In the field of applied science and technology, however, priorities should be established by considering either the possibility of utilization of local natural resources, or the need for importation of so-called advanced technology, without which the speed of development will be a frustratingly slow one.

A field in which these specialized institutes have a special role to play is that of food protection. They have to take as goals in their work the increase of productivity of the soil, of edible proteins and dairy products, the technology of industrialization of agriculture, the obtention of new sources of food, conventional or not, better techniques of food preservation, and so forth. This is a problem as acute as can be, demanding immediate action, because the population increase in Latin America brings along the specter of hunger.

Another problem to be referred is that of the purchase of imported laboratory instruments, or their eventual manufacture in each country. For the primary and secondary scientific education, the problem, if not solved, is at least well equated. In São Paulo, the pilot experiment already mentioned shows how a rather inexpensive solution can be obtained. The present transformation of the São Paulo center into a nonprofit industrial organization, the Foundation for the Advancement of Scientific Education, and its natural expansion as a consequence, will help to establish data to be easily followed. It may serve as an example to all Latin America. The commercial output of such a line of production guarantees its success. This is not valid for the current laboratory instrumentation, used in graduate training and research. It is my belief that governments should be encouraged to establish such basic national industries, and precision shops at the "centers of excellence" in the universities in general.

The last measure will enormously facilitate work in the laboratories. The first one may be a solution to the present situation in which a nonsophisticated national instrument, unless it is of a very simple type, costs more than a sophisticated foreign one. Establishment of such a policy in a commonsense manner would permit the increase in the importation of nonstandard equipments, costly but indispensable machines, and a more realistic approach to the problem.

International help at the present time is essential in this field. The devaluation of national currency is such, in general, that probably the great majority of all equipment Latin American institutions have been

able to renew, only to keep some of their laboratories up to date, was made possible only through external aid. It is probable that this situation will have to be maintained in the near future. Notwithstanding the danger of the so-called fetishism of equipment, external aid should be concentrated in this field, preferably in the form of long-range, low-interest loans.

National counterpart, evaluated in national currency, should then consist in the official measures necessary to upgrade local scientific and technological research.

Regarding the very costly apparatus, which are a great part of modern research, a policy must be envisaged of centering them in a national scale as much as in a regional one, so that they could be used in a full-fledged manner. It is a pity that in some cases, due to the various national prejudices, it has not been possible to establish such a pattern on a regional basis.

There is still a last point to be focused. It refers to the publication of textbooks. To choose between a policy of translation, and that of stimulating the obtention and publication of local originals, is not easy. Probably a great effort should be undertaken at once in the first direction, to be followed afterward in the second one. If the problem of textbooks can be equated, and its solution seems easier in the Spanish-speaking Latin America, that of current information furnished by scientific and technological periodicals can only be solved by a constant insistence on a thorough teaching of a second language as part of any technological and scientific education.

Table III.—*Latin American scientific production compared with total production*

	Year	Total titles	Total copies, 10th[1]	Basic sciences number of titles	Applied sciences number of titles	Percent of total titles, both categories	Percent of total copies, both categories	Percent of translated titles, both categories
Argentina	1961	3, 703	----------	41	189	6. 2	----------	20. 0
	1964	3, 319	----------	92	229	9. 7	----------	20. 0
Brazil	1961	3, 911	----------	40	273	8. 0	----------	19. 5
	1964	4, 809	47, 805	36	270	7. 2	3. 2	7. 6
Chile	1961	1, 389	----------	50	314	26. 2	----------	----------
	1964	1, 577	----------	20	154	11. 0	----------	----------
Cuba	1961	698	----------	17	88	15. 0	----------	----------
	1964	509	----------	12	90	20. 0	----------	----------
Mexico	1961	2, 679	----------	277	839	41. 65	----------	9. 1
	1964	4, 661	----------	452	1, 757	47. 39	----------	4. 7
Venezuela	1961	338	----------	9	39	14. 2	----------	----------
	1963	743	----------	14	195	28. 1	----------	----------

[1] No Latin American country figures in the list of the 10 most important book producers from 1960–64. To be noted that Spain is listed in 6th place in the 1964 list.

This is in large terms a tentative program for science and technology in Latin America. It has to be ambitious, because we are dealing with a problem which becomes more acute, not to say dramatic, every day; that of the social changes produced by a rapidly increasing population. The disequilibrium that the ecological conditions presiding over this social evolution are producing deserves ample attention, and a courageous attack. Let us try, however, to assert the feasibility conditions for its success.

We shall begin by trying to ascertain, in a very desultory manner, the expenditures related to research and technology in Latin America. Statistical data on the subject are not easy to collect, and some of them present

TABLE IV.—*Public expenditure on education*

	Year	Total national currency	As percent of national income	30 percent
Argentina	1960	22,225,000,000 pesos	2.3	0.69
	1964	73,686,000,000 pesos	3.2	.96
Brazil	1960	55,000,000,000 cruzeiros	[1] 2.4	.80
	1964	441,000,000,000 cruzeiros	2.4	.80
Cuba	1962	226,385,000 pesos	7.8	1.38
	1964	210,355,000 pesos	5.0	1.50
Chile	1954	8,331,489,000 pesos	1.8	.54
	1963	264,579,000 escudos	3.2	.96
Colombia	1954	155,565,000 pesos	1.4	.42
	1963	1,158,015,000 pesos	3.3	.99
Mexico	1950	312,300,000 pesos	.8	.24
	1963	5,175,026,000 pesos	3.0	.90
Peru	1950	246,100,000 soles	2.0	.60
	1963	2,680,118,000 soles	4.9	1.47
Uruguay	1961	451,000,000 pesos	3.1	.93
	1963	584,588,000 pesos	3.0	.90
Venezuela	1950	122,200,000 bolivares	1.4	.42
	1964	1,049,946,000 bolivares	4.0	1.20

[1] National gross product

an original bias produced by a wrong method of collection. Our analysis has thus to limit itself to very general terms. Studying the expenditures, according to the available figures, with reference to higher education, one observes that they have not increased appreciably or even not at all, if the index taken is the relation between expenditures and gross national product. Taking 30 percent of this value as the expenses for research and development—a tentative criterium adopted in some national surveys and by some international agencies—we are close to the 2 percent value from the total budget, proposed in some international conferences as the necessary minimum for development, as this percentage corresponds to about 0.7 of the gross national product. As a matter of fact, at CASTALA (Conference for the Application of Science and Technology to Latin America), the minimum of 0.7 percent to 1 percent of the gross national product was considered as one of the goals to be attained.

I would like to discuss these data under the following arguments:

(*a*) it is rather doubtful to admit that 30 percent of total expenditures in education are devoted to science and technology in Latin America, in view of the structure of the institutions in place. One may admit that the budget of other departments not included under education would supply for the difference. In this case, it would be a new proof of the inefficiency of the basic structure;

(*b*) the values proposed (2 percent of the total budget, 0.7 to 1 percent of the gross national product), seem to have no meaning. As a matter of fact, the participants of a recent conference held in Algiers under UNESCO's sponsorship, came to the conclusion that no fixed tax can correspond to the actual needs for such programs, and that the significant figure to be taken in consideration is the rate of increase of total investment in science and technology.

If this criterium is correct, then the Latin American situation is disappointing. The impression is nevertheless that it will fit better the observed facts.

To prevail over this situation, two types of action should be considered. Regarding the economics of the problem, the first move would be to convince governments and international financing agencies that investment in education can no longer be considered as a preinvestment, but must be

part of the process of investment itself. There are many arguments in support of this thesis. Considering the study of Edward Denison on the United States, in which he states as 23 percent the economic growth since 1929 due to the expansion of education, and 20 percent that of research, one has to admit the proposed point of view.

Certainly, the numbers presented by Denison are subject to modification, and the models he employed in his analysis, to criticism. However, his conclusion shows how far we are from considering education simply as a consumer's good. It is rather perplexing to see that the harshest of the critics of Denison's conclusions are willing to concede that the renewal of equipment—because shown pragmatically—has a direct bearing on the increase of productivity. It seems that, concurrently, the renewal of knowledge in its two forms, formative education and permanent education, must have at least the same significance as that of equipment. Thus, education and research should be considered at least capital incorporated investment.

Now it is clear that the Latin American economy has not attained the point where the capital investment has reached saturation and the need for an increase of investment in research is necessary in order to produce further growth. But it does not mean that we should maintain ourselves in the classical lines which correspond to the rich countries' economy. Many economists believe that this is not the case for less developed countries, and particularly for Latin America. The case requires a stronger push in the upgrading of marginal values.

There are, however, other factors which come to play. It is said that stretching investment in education, research and technology may create unfavorable social conditions. It is clear that Latin America has not reached that status yet. However, it needs better management and courageous measures for its scientific and technological development. One has to determine a better rationale for the use of present financial resources, thereby achieving an immediate change in the picture. Needless to say that education and research are not economic panaceas. They can only be useful if integrated in the social structure of the countries.

I would hazard myself into saying that education and particularly scientific education, is still more urgently needed than research in Latin America, because development is essentially a state of mind.

This is the ultimate goal; and, unless the whole society assumes the necessary attitude, all measures here proposed, or the others to be much better outlined by someone else, will be fruitless.

Many times in the history of mankind, social revolutions have tried to establish that unanimous state of mind. They have brought unwanted episodes of violence, deceit and blood; but, together with benefits, they have failed to bring with certainty joy, spiritual fulfillment, and happiness, which are also a part of man's role as the salt of the earth. Leaders have also tried it by force: their efforts have also failed, and have had, at most, the ephemerous duration of a human life. Only education effected in the spirit of science can bring the attitude and the unanimity of intentions which will produce social development. In implementing the initiatives of realizations which bring relief, let us not forget that the benefits they bestow can last only if promoted within the frame of knowledge and understanding which bear the mark of education and research.

This is the task of modern Latin America.

[illegible]

WORLD COMITY THROUGH SCIENCE AND TECHNOLOGY

Donald F. Hornig

The theme of this Conference, "Government, Science and International Policy," might have been a highly theoretical one a quarter of a century ago, but that is no longer the case. Through nuclear weapons, rockets, and satellite communications, for example, it has become abundantly clear to the public that the applications of science are playing a major part in shaping the world of the present and the future. Perhaps less dramatically, but just as important, most governments have recognized that in the long run the ability to conquer disease, to improve health, to produce enough food to ease the hunger of the world's expanding billions, to meet the material needs of the population and to satisfy social goals, all rest on the applications of science. In many cases, progress in these respects depends on the application of scientific principles which have yet to be discovered.

And just as the ability of nations to meet their own goals in the long run depends on their cultivation of science, so it is almost a truism to say that in the long run the relative power of nations, and the relations among them, will be shaped to a considerable degree by the progress of science and the uses which are made of that progress. This is, of course, widely recognized. It is the reason why some people in Western Europe are deeply concerned with the so-called technological gap which they feel is developing.

The realization that science is an important force in world affairs is what brought about the establishment of an active Office of International Scientific and Technological Affairs in our State Department. It results in our having science attaché posts in 17 embassies throughout the world, and the fact that in 26 embassies in Washington there is at least one full-time officer working on science matters. Science is a key component in international organizations such as UNESCO, the Food and Agriculture Organization, the World Meteorological Organization, the International Atomic Energy Agency, and the World Health Organization. Scientists are in the forefront of the discussion of means to stabilize the arms race which threatens the future of the world and in seeking means to control nuclear armaments. They are playing a new and expanding role in governmental and international activities because of the widespread recognition that this is a new and vital force in shaping the world of the future.

I would like to spend a little time inquiring into the ways in which science can improve understanding between nations.

Scientists have always played an international role. They constitute an international community which approaches common problems from a common point of view and works from fundamental premises which are not national in origin. Wherever they live—the Soviet Union, China, Western Europe, America—they share a common interest in solving the problems posed in understanding natural phenomena, in rationalizing the natural world around us, and in utilizing that understanding and the skills

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acquired for the benefit of mankind. Many scientists are extremely ambitious for what science may do for the world and see in the evolution of science a possibility of an "end run" on longstanding political, social, and economic problems, both national and international, by offering the world new alternatives based on scientific advance. Interestingly enough, these points of view are widely accepted even outside the scientific community.

How can this international community contribute to international relations? It may be worth making, first, some points whicn are perhaps obvious but which need to be kept in mind. In the first place, science is not made international by cooperative agreements, by international organizations, or by the actions of governments. It is intrinsically international in character, probably more so than most scholarly disciplines. Why is this so? The subject matter of science knows no nationality. The stars in the sky, the distant galaxies, raise the same questions for astronomers everywhere. The molecules of the chemists have no ideologies. The plants and animals of the biologists, the genetic codes of the biochemists, are universal. Nuclei and the fundamental particles which compose them are a challenge to thinking men everywhere. In short, the problem of basic science is to isolate characteristic phenomena in nature by experiment, to fit those phenomena into a general framework of ideas, and to discover the basic laws in terms of which we can understand nature.

Of course, the applications of science do involve competition among nations, but even then the subjects to which they are devoted derive from the same laws of nature, the same principles, and the same experimental observations.

Perhaps as important as the universality of the subject matter in science is the universality of the approach to scientific problems. There are no distinct national styles as there are in music, or in art, or in poetry. Perhaps the reason for this is that whatever the line of argument or the theory it must be tested in the end by predictions which can be checked against other experiments. The makes nature itself the arbiter. The reasoning in science is forced into a certain objectivity which is harder to find in some other intellectual disciplines. For example, in the recent Chinese synthesis of insulin, a feat of Nobel Prize caliber, the experimental approach was similar to that in the West. The motives were probably the same as in the West. Thus, when scientists gather at international meetings, they have a common outlook and talk a common language. Although there are feelings, emotions, and sometimes violent differences, they proceed from common basic assumptions which transcend the nationality of the participants. Whatever their basic politics, they usually have a common sense of scientific values.

Of course, all of this might be just fine for the scientists; it might be the basis for a kind of cult or fraternity. But what makes it important to governments of the world is the universality of the interest in the achievements of scientists. Science has built an understanding of nature and its laws which is of the utmost practical import to everyone. More deeply than that, it is a part of the human culture of the 20th century. The ideals of science have woven their way into every culture on the globe. Despite cultural differences, East, West, Communist and capitalist countries all have found a place for science in their culture.

One of the greatest achievements of science has been an effective communication pattern. At the heart of it is the scientific journal in which the individual scientist reports the results of his experiments and observations,

develops his interpretations and his theories, and tests them against other experiments. In the chemistry department library at Princeton University, from which I came, for example, we received each month some 250 journals from almost every country in the world—from the United States, from Western Europe, from the East bloc countries, from the Soviet Union, from India, from Japan, and many others. Abstract journals print the significant findings from all the journals published anywhere. For example, *Chemical Abstracts*, which is read by most American chemists, abstracts over 5,000 chemical journals. By keeping close to his subject, each scientific worker is acquainted with other workers throughout the globe, at least by reputation.

The formal publication net is frequently supplemented by extensive personal correspondence. However, written communications are inadequate, so that in addition to the scientific journal, the abstract, and the personal letter, international meetings of all sorts are necessary for scientific progress. These range from the very large meetings conducted by the great international scientific unions to the small symposia on highly specialized topics. Their role is to bring together scientists faced with similar problems who compare notes on their ideas, on the instruments they use to tackle the problems, and on the means of solving them. It is this communications net which binds the scientific world together so that most scientific researchers are a widely traveled lot who feel themselves part of an international community in which they count a wide circle of friends and colleagues throughout the world.

Now here I would like to make an aside. I have emphasized the international character of the subject matter of science and the relatively effective international communications scheme. But the pattern of communications doesn't come about automatically; someone has to organize it. This has taken place historically through the great international scientific organizations. There is the International Union of Chemistry; the International Union of Physics, and so on, under the auspices of the International Council of Scientific Unions. These international unions bring together the national organizations which also participate in the organization of science. Among other things, the unions establish the standard terminology which makes it possible for scientists everywhere to talk to each other; they help set the standards and agree on the units which scientists use. International organizations sometimes go further and organize international collaborative efforts.

I have idealized the picture somewhat. The communications may be better in science than in most areas of human endeavor, but there are still real barriers to exchange. The scientific terminology of all scientists may be very similar, their outlook and approach may be the same, but differences in language *do* inhibit the commonality of their approach. A more fundamental problem in scientific communications is the unevenness of scientific experience. The fact that all scientific results are available in print everywhere in the world does not constitute true communication. Deep, intimate communication only really occurs between men of roughly the same level of training who have had a certain community of experience. This is not just a matter of book learning, but of experimental methods and instruments. There must be, just as in ordinary personal contact, a common interest and a common experience between scientists who are to communicate. This produces a problem for the developing countries, where often these conditions are not met. The developing countries have the additional handicap that when their workers have not been trained to the same level and have not had contact with advanced experimental

methods, they find it much harder to assimilate the new ideas and approaches than do the corresponding workers in the advanced scientific countries. This is a problem to which we must address ourselves.

Given all the considerations I have mentioned, many forms of collaboration between scientists throughout the world have been developed during the last century. Scientists visit one another's laboratories; they deliver lectures at universities in foreign countries; they visit facilities and see the new tricks of the trade which are being developed at their collaborators' laboratories. This bread and butter collaboration has been taking place on a very large scale. For example, some 800 scientific workers traveled between Czechoslovakia and America last year, and a much larger number between the United States and the Western European countries.

A more formal type of collaboration occurs when the problem itself is international and requires collaboration for its exploration. For example, the earth's atmosphere is not the property of any single nation. The phenomena observed over any one country alone are inadequate to understand the atmosphere or to form the base of an adequate weather forecasting system. The understanding of the earth's atmosphere will necessarily require the collaboration of nations across the entire globe. This cooperation has been formalized in the world weather program under the World Meteorological Organization in cooperation with the International Council of Scientific Unions. Oceanography—the science of the oceans—similarly belongs to all of us. Here intergovernmental cooperation takes place in the International Oceanographic Commission of UNESCO and in the Special Committee on Oceanographic Research of ICSU. There are several other important international cooperative projects now underway, including the Upper Mantle project, the International Hydrological Decade, and the international biological program. These international programs include all of the basic forms of collaboration in joint planning and shared work, and finally collaboration in the solution of worldwide problems.

Until now I have spoken only of the intrinsic internationality of the scientific enterprise. You may well ask, where do governments come into this and how do they benefit? One way is that they pay the bills. Even when formal intergovernmental arrangements are not involved, funds are required for international meetings; funds are required if scientific exchanges are to take place; and funds are required if scientific journals are to be published. In the modern world most of these funds must come from governments. And why do they pay this bill? Because modern society has a deep stake in scientific progress.

As the scale of the national scientific efforts have increased, the opportunities for large international ventures have expanded, and governments have acquired a deeper role which poses larger problems. When the demand for funds greatly exceeds available support, governments necessarily have to exercise choices, and this puts them into the business of deciding what the significant areas of collaboration are and what forms it should take. There is no way of avoiding this problem, but it poses a new set of concerns in that the criteria of choice which are exercised by governments may not be based on a real understanding of what is possible and what might be fruitful.

Bearing all this in mind, the central question then is what we can do now so that this international community of science can benefit world peace, advance world progress, and develop understanding between nations.

As far as the basic sciences, mathematics, astronomy, chemistry, physics, biology, geology, and so forth are concerned, it does not seem to me that

fundamantal changes are in order. It is in all our interests to maintain an effective exchange of ideas, results, and personnel through all channels available. The chief problem I see is the increasing desire of governments and international organizations to cast exchanges into rigid molds and to pick areas and modes of collaboration on formal grounds. We have excellent intergovernmental agreements such as the United States-Japan agreement. Nevertheless, in the basic sciences it seems most desirable to avoid formal governmental channels. Rather, flexible arrangements through international organizations, scientific societies, national scientific academies and universities are generally more fruitful. When special stimulation is desirable, as is most often the case with developing nations, governmental agreements should allow considerable freedom as to areas and modes of collaboration if maximum benefit is to be obtained.

There is at least one area, however, in which more formal steps are needed. The volume of scientific effort and the volume of scientific publication has increased so greatly in modern times that there is a real problem of how to get information from the man who generated it to the potential users. This is the problem of the storage, indexing, and dissemination of scientific results. We are making a great national effort to improve these systems. However, when one considers that this effort at abstracting, indexing, etc., is duplicated in many countries, it is also clear that there is an important need for a stronger international effort to systematize and improve scientific communications despite the fact that they are perhaps the best and most systematic communication system available in the world. They need to be much better if we are to cope with the rate of growth of output, for even the best informed scientists now have difficulty keeping in touch with all that is going on.

In this connection, the less developed countries have a particularly difficult problem. They must preserve a window to the modern world and must somehow acquire libraries, books, journals, and copy machines which will help them to disseminate modern scientific works from complete central libraries. We must assist in setting up cheap printing and reproducing schemes by which good, modern texts as well as modern research works can be disseminated.

I have talked about the importance of the exchange of scientific workers, and in this connection there is a special problem concerning students. In an open world a talented man ought to be able to seek the best education he can get anywhere. And it is certainly laudable that this country makes its universities and laboratories available to talented students from everywhere on the globe and provides them with fellowships, research assistantships, and so on, to enable them to come to America to avail themselves of the opportunity. This is one of the most effective ways to assist many of the developing countries in gaining access to the best of modern science.

But you are all aware that often something else happens. Many of the students either stay in this country, or go home and then return to this country. This poses a very difficult problem, because it seems unimaginable to me that we should erect obstacles to the free flow of people and particularly to the flow which enables the most talented people to find the best outlet for their abilities. With this in mind, I think nevertheless that we might consider a change in some of our practices. We should certainly not put up barriers, but we might consider changes which would insure that we do not subsidize the large-scale transfer of talent as an unplanned consequence of Federal support of research. It appears to me, for ex-

ample, that we should review the use of public research funds to bring in foreign graduate students and postdoctoral researchers for advanced work in this country unless their appointment had been screened in some appropriate way. In my view the purpose of international exchange would be better served through funds that are concentrated on young research scientists who have already established themselves in their own country, who come to America with a purpose related to their activities in their own country and who have something to return to. This would not solve the problem of the "brain drain" but it would mitigate it and place the problem in proper perspective.

Another area in which international collaboration can be developed is through the mutual use of "big" facilities. What I have in mind here are large astronomical telescopes, large atomic accelerators, spacecraft, and so on. Of course, this is already happening. European workers come to the Brookhaven National Laboratory to use the 30-billion-electron-volt accelerator there and American workers go to CERN in Geneva. I think, however, that more funds might be systematically provided to facilitate the mutual exchange of workers, not for the purpose of economy, but so that the best possible experiments are conducted by the people who have the best ideas for the use of each large-scale piece of equipment.

This gives rise to another suggestion which I think might have merit. A powerful force for the improvement of American science has been the scheme of research grants which were not distributed among States, were not directed to institutions, but which were directed toward the most talented and capable individuals with the best ideas wherever they existed. Many other countries have adopted their own versions of this form of support, and limited efforts to use it have been made by international agencies. Perhaps the value of the project form of support based on the merit of individual investigators in less developed countries should be explored more thoroughly. It should certainly be possible to set up panels of outstanding scientists in various fields from both advanced and less advanced countries to judge the quality of research proposed. It could be funded through an existing international agency or a consortium of the advanced countries. Such a plan would have to be carefully thought out. For example, it might prove necessary and desirable to set up regional plans rather than to have all less developed countries compete with each other for a single fund. And it might be desirable to establish a reasonable linkage between this form of support and primary national needs, by setting up earmarked funds for special areas of science. However, I am convinced that such problems can be solved and that the basic idea has merit and should be pursued. It would stimulate quality in the developing countries and profit the advanced nations as well—for they are in a position to assimilate scientific advance wherever it occurs.

All of these comments, of course, are directed really at the notion of establishing a kind of world scientific economy—similar to what this Government has been trying to do in establishing a larger world economic trading area by lowering tariffs and eliminating trade restrictions. I would like to see the same sort of thing happen in science, using every means at our disposal to promote the free flow of scientific talent, of scientific ideas, of scientific opportunities, recognizing that it is in our interest to develop good science everywhere

When discussion shifts from basic science to applied science and technology, a new and equally complicated set of considerations comes into play. Technology can be usefully discussed under two broad headings.

First, there are those aspects of industrial and military technology which have a direct bearing on prices, products, and competitive positions in the current market. Here the considerations are complicated, but it is clearly possible—and we should attempt—to expedite the flow of technical skills and know-how while protecting the results of private efforts.

One of the ways in which science and technology are making important contributions to international understanding is that most advanced countries, in varying degrees, are attempting to assist the economic and social development of the less developed countries. To a large extent, this is a problem of introducing modern technological methods into industry and agriculture on a short time scale—much shorter than was the case in the societies which originally developed the technologies. What is not always recognized is that this process of innovation and adaptation must be accompanied by strenuous efforts to educate more scientists and engineers, and more active interchange between the advanced and less advanced technoogical communities.

It is sometimes asserted that this interchange is not needed, and that technology can be simply imported. But to be in effective contact with advanced technology and to use it effectively for economic development, there must be some people in the less developed countries with such levels of training and practical experience that they can communicate effectively with their counterparts in advanced countries.

However, there is a second broad area of technology in which more extensive international collaboration is clearly called for. This area includes the problems of health, pollution, of roads, of communications, of urbanization, in which all nations have a stake and in which common solutions can be found. Here collaborative efforts must be doubled and redoubled. These are problems in which all the efforts all of us can make are not enough. The real problem is not to eliminate duplication of effort, but to so relate the effort and the planning that what is done in each country adds to that of the others. For this purpose I advocate flexible international arrangements with emphasis on good communications and joint planning of efforts.

I have run over many things today, but they all revolve around a common theme, that in scientists, engineers, and technologists, we have a large international community of people who understand each other, who think similarly on many problems, and who tackle problems from a common point of view. In general they have also a common interest in solving problems and a common aspiration to circumvent the problems of the world with new and heretofore untried solutions.

I have one final plea, too. Since this world scientific and technical community has so much in common, I think it would be wise to bring it further into the discussion of the large group of international problems which are not in themselves technical, but which have large technical components, where the analytical cast of mind and sound view on the nature of technical change might be put to use. This has already occurred in some parts of the world, but usually not to the extent that it has within the United States, where scientific and technical people are now present at the policy level in every major part of the government. It seems to me we can make progress on the world scene if the particular flavor brought by the scientists and the engineers is incorporated intimately into our discussions of disarmament, world economic development, world food, population control—in short, to the total development of mankind so that he can gradually free himself from the restraints of nature and realize the goals of his dreams.

GOVERNMENT-INDUSTRY PARTNERSHIP IN SCIENTIFIC APPLICATIONS, WITH SPECIAL REFERENCE TO THE NETHERLANDS

H. W. Julius

Science and industry in their unprecedented development have become firm partners. This is a fact so well recognized that mention of it is almost a commonplace. The relationship is generally looked upon as self-evident. Nevertheless there are problems and even tensions. Unmistakably. For, if not, why then, Mr. Chairman, would your esteemed committee have brought this day's subject up for discussion?

All those responsible, in one way or another, for the all-important economic development of their countries rack their brains to find the balance within the many complicated relationships in this modern "eternal triangle" of government, industry, and science.

Add to this that the picture is thoroughly different in the several member-countries of our world family of Nations and we may become aware of the dimensions of the problem we are dealing with.

In trying to consider the content of the triangle, there can be no other starting point for someone in my position than what is going on in my own country. This sounds rather self-concentrated, a trait that I myself do not appreciate very much, so please, Mr. Chairman, feel behind my outline the essence of the general problems that could be tackled in many different ways. Ours is one of these and, as I know for sure, certainly not the most desirable one.

The "Low Lands" near the sea have largely been wrested from the water. No doubt this has caused the Dutch character to be very conservative on the one hand, progressive and enterprising on the other. This quality is real and significant; it generally entails a rather complicated structure as will be clear in a few moments. I shall have to apologize for this complexity beforehand.

For a proper understanding, two more of the Dutch nation's traits will have to be brought into the picture.

The one is that old sailorship has founded the Dutch tradition of a trading country from which stems the present days' mentality of commerce that predominates in the nation's style.

The other trait is the country's love of liberty. It roots historically in the Reformation which—again—was the expression of the country's strong contention for freedom of thought, even to such an extent that up to the present moment the rights of others for different views will not be disclaimed. On this basis stands Holland's universally forebearing attitude and it is at the root of today's mutual tolerance of many different opinions, approaches, and solutions.

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I have deemed it essential to give you this very short picture of the nation's background in order to enable the best possible understanding of the only approach possible to me, i.e. the subtle Dutch structure in relation to your subject.

History and Philosophy

The words "science policy," "research and development," "research management," and the like, are modern terms. But we should not fail to recognize that, without being in the least applied consciously, at the end of the 19th century the same concepts were operative already. About 1880, while the country was still agricultural throughout, it was struck by a not far from catastrophic agricultural crisis.

Desperate poverty of the peasants left no other way out than action taken by the Government, the first help being instruction and guidance to the farmers. This proved to be a wise policy but it was not enough. Soon it became clear that effective information should spring from solid knowledge. So the Government decided to establish a number of scientifically run stations for soil analysis, comprising test plots on arable land, and laboratories of a mainly chemical type.

In Holland this was the first and well conscious effort to support one of the essentials of the nation's economic structure through science.

The effect was highly encouraging, so much that even today our agricultural yield per acre is among the best of the world. Small wonder that ever since the quintessence of Holland's organizational pattern for science to be instrumental in promoting the nation's welfare has been essentially a responsibility of the Government. This is not limited to the domain of science; in most matters of public interest, social security, health, education, recreation, and the like, the governmental predominance is the rule. In many countries this structure is less favorably looked upon. However, there is a good reason for its being generally accepted in my country. It has always been part of the authorities' policy not to suppress private initiative; on the contrary, interest and action privately started have always been stimulated by the Government through subsidizing and still avoiding display of power and dirigism.

If I add that the universities, even the confessional ones, and the technological universities are the full or nearly the full financial responsibility of the Government, you will appreciate that the scientific community in Holland is used to addressing the Government for means for research. Of course, for one branch of scientific research this definitely will not hold good; namely, that performed by the industrial company for the sake of its own commercial position. But even where industry cannot afford its own scientific setup, the Dutch Government feels its responsibility just as it did in the eighties for agriculture.

Between the Two World Wars

When the First World War had come to an end it had become clear, even to the Netherlands, which had remained neutral, that science and research were about to get a decisive influence on the total structure of society in all its aspects; an influence that after the Second World War turned out to be a multiple of all expectations in the twenties.

Nobel Prize holder Lorentz, at that time chairman of the Netherlands Royal Academy of Sciences, and, some years later, his successor in this

function, chaired two successive committees both studying how Dutch science and research could be organized to insure the best possible service to the nation's prosperity.

In 1930 a bill passed our Parliament to become an act by which a body corporate came into being called the Central Organization for Applied Scientific Research, the aims of which should be "to insure that such research is put at the service of the community in the most efficient manner possible."

It is around this organization that revolves the relationship between government, science of the oriented type, and private enterprise, industry in particular, together with other social sectors. So I will confine myself to this organization and neglect intentionally a small number of institutes not belonging to it.

Start and Development of the Organization; Second World War and After

The start of the organization has been a difficult one. When World War II broke out, the organization was nothing more than a very limited trial and hope for the future, and its yearly budget was only Df 450,000. During the German occupation, however, the great and sad difficulties of the universities worked in favor of this still fully unobserved organization. When war was over, the organization had gained its ground. It had some institutes working, albeit under rather primitive and provisional circumstances.

By 1945 the reconstruction of the heavily damaged country could start. Its economy, more than under previous conditions, had to concentrate on industry without in the meantime neglecting its classical agricultural nature. The still young organization then got and seized its opportunity. It supplied the want and developed to its actual dimensions, now about fiftyfold of the volume it had at the moment of liberation in 1945, when its budget amounted to Df 2,500,000.

I shall now come to brass tacks, but not without having first apologized, Mr. Chairman, for this rather contemplative introduction. I could not do without this background, indispensable for good understanding; this I know for sure.

The organization just mentioned, the chairman of which is the speaker of this moment, may for short be indicated by the three initials of its Dutch name: TNO standing for Toegepast (applied) Natuurwetenschappelijk (scientific) Onderzoek (research).

Its legal structure is the following:

The Central Organization for Applied Scientific Research can be considered the axis on which turns the Dutch system of government-industry partnership in scientific applications. As I said, it is a body corporate, created by law. The ultimate responsibility of the organization is vested in its board, the members of which are appointed by the Queen by and with the advice of the ministers who have countersigned the act. An eventual shift in the division of ministerial departments has been taken into account.

To quote from the law: "One-half of the ordinary members shall be appointed from among persons considered to be expert in the field of the natural sciences and the other half from among persons considered to be expert either in economic affairs generally or in those economic interests which are served by the natural sciences."

In addition, so-called temporary members can be appointed on the same basis when—I quote— "special circumstances render it desirable."

The number of ordinary members is related to the number of ministries interested in applied scientific research; the number of temporary members is unlimited. Most members and temporary members are appointed for 6 years and are eligible for reappointment. The age limit is agreed upon to be 70.

At this moment the board numbers 26 members.

By it are ruled and controlled the budget of all TNO organizations, the setup of which I will explain right away, as well as the yearly account of the whole organization which is rendered directly to the Queen. The board has an executive committee to which the routine management of the organization is entrusted. It is this executive committee which factually is life and soul of the whole organization.

The board appoints a secretary and a treasurer. Their assignments relate to the proper running of all the administrative functions of the family of TNO organizations.

The domain of applied scientific research in the Netherlands is much too vast and also far too much divergently specialized to have all its activities, servicing of social groups, and widely branched contacts combined in one organizational body. Therefore the act provides for so-called special organizations, each having the status of body corporate. They serve special fields or social sectors for which applied scientific research is indispensable.

The special TNO organizations are called into existence by statutory order in council, either on the recommendation of the Central Organization, or after its being consulted by one or by more than one minister in their joint interest. The names of these organizations bear the indication of the field they serve.

Four of them have been established; I give them in the order of historical seniority:

(1) Organization for Industrial Research TNO (1934).
(2) Organization for Nutrition and Food Research TNO (1940).
(3) National Defence Research Organization TNO (1946).
(4) Organization for Health Research TNO (1949).

Each of the special organizations has a Board, the composition of which is largely comparable to that of the Central Organization. They may have executive committees (in fact only one has not) so that their way of working is a rather true copy of that of the mother organization.

That this family of research organizations shall intrinsically be an entity has been safeguarded by several measures.

Under a statutory order in council the executive committee of the Central Organization consists of the (four) chairmen of the special organizations and the vice chairman of the Central Organization plus the chairman of the Central Organization, who, of course, also chairs its executive committee. *This committee meets weekly;* all matters of actual and general importance are discussed, considered and, as and when necessary, prepared for decision. For the necessary contacts, the chairman of the National Council for Agricultural Research joins these meetings. Actually the fact that all members of the Executive Committee have offices in the one main administrative building of the organization makes for easy contacts.

The secretariat and financial administration of each special organization are provided for by the secretary and treasurer of the Central Organization. The budgets are combined into one overall budget which is subject to im-

provement by the Board of the Central Organization. The special organizations are bound to report on their activities at the end of an administrative year to the Central Organization. On the basis of the overall budget, the Government grants an annual subsidy to the Central Organization, which divides it between the organizations. The bodies corporate are then entitled to spend their respective assigned parts. Under the "TNO act" the Board of a special organization shall furnish the Board of the Central Organization with all the information it may require. In this context it should be kept in mind that the chairmen of the special organizations are members of the executive committee of the Central Organization.

All this will, no doubt, make the impression of being a rather complicated matter. And indeed it is! But with wise men in the chairs and on key positions, in the bureaus of TNO organizations and, finally, in the ministries, it has proved to be well workable. This does not mean that having a number of five bodies corporate to really work together, and thus make them serve one national goal as well as their own field of action, can be called an easy task. But the more the present speaker has got to know the TNO organization, the more he has learned to appreciate its original and visionary farseeing idealism, which still is the strong cement that has built it.

The Triangle: Government-Enterprise-Science

The side of this triangle best to be drawn first is the one that can depict the relationship of the Government to TNO, its own creation: Chapter I, section 3 of the act reads—briefly and to the point—"The Government shall grant the Central Organization an annual subsidy." The maximum amount of this subsidy will be determined by the Minister of Finance.

This brings us to the very heart of the matter:

The organization has arisen from the original conception of governmental responsibility as to where science could contribute to the community's prosperity. The setup having been created, the responsibility for its upkeep and maintenance lies with the originator!

In 1932 the Central Organization started with a one-man office and 12,000 guilders governmental subsidy! The next year saw a lady secretary join and the subsidy rise to 20,000 Dutch guilders. (For comparison divide by 2.5, which will not yield the dollar equivalent according to international exchange rate, but rather the equivalent according to purchasing power.)

In 1940 the governmental subvention was nearly 400,000 guilders. At the end of the war (1945) it had increased to 2.5 million (equals $1 million on purchase basis).

For the 1966 fiscal year the governmental subsidy has been roughly Df. 67,000,000, plus 20,000,000 for building investment.

I pointed out that by law was created an independent body in order to have its policy made by experts and men of experience and with a view to placing it in a free position toward anyone, be it government itself, industry, defense, medical world, consumers, agriculture, and whatnot. To put a scientific organization in such a position had been a point of controversy when the first steps into the field of service-by-science were taken. However, it *has* been done and that is how it is. Meanwhile, it should be noted that the fundamental law that "he who holds the strings of the purse will rule the roost" has not been and should not be abandoned! Each of the ministers who signed the law, also each of the ministers who have called a special organization into existence and—last but not least—the Minister of Finance will propose for Royal nomination a functionary—

civil servant of their respective Ministry—as a delegate to the Central Organization, or the relevant special organization. All these functionaries are entitled to attend the meetings of the Central Organization, the delegate of the Minister of Finance preeminently so; the delegates of the ministers, sponsoring special organizations will attend the Board meetings of these organizations. Essential in this context is that, at the places and moments indicated, they have the "right of veto" (they are competent to lodge an objection to decisions made by the respective boards).

This sounds very rigid or even polemic. In practice, however, in all the length of the organization's existence the veto has been made use of only once or twice. In fact the very existence of this right is a sound basis for frequent and open consultation and exchange of views and plans, which results in avoiding as effectively as possible the mutually disagreeable position of putting the process of veto into action.

Besides, the system of delegates warrants a good dictate of the ministries in the actual policy decisions of the boards.

All this is very well regulated and under control. Nevertheless it will not be the regulations but it is the men on which the system runs. To make this very clear: even with the best type of rules and regulations an organization will fail unless the humans, working in its context, agree and strive to make it run. Holland, in addition, has one built-in advantage: it is a small country, everybody knows everybody else. This is an essential lubricant in the machine!

To the best of my knowledge the TNO-organization is the only non-governmental body that has direct contact with and access to the Ministry of Finance. This ministry submits to the other ministries that are directly concerned with activities of any of the TNO family of organizations "a proposal regarding the distribution of the said subsidy over the appropriate heads of the national budget." By doing so, any of the ministries as well as the whole of parliament, and in addition the general public and the press, are regularly informed about the TNO activities and about the broader fields in which they take place.

Now, Mr. Chairman, I must draw the second, and in our context the most important, side of the triangle, viz the relationship between science and industry.

The terms of reference of the TNO-organization, as I already said, are very broadmindedly formulated. As to the task of the organization there will be no more engaging or restricting precepts than "to insure that applied scientific research is put at the service of the community in the most efficient manner possible."

The organization "shall be authorized *to study problems in* the field or to *have such problems studied*, to *advise* persons or institutions and in general to *foster and support applied scientific research* and *the application* of the results it achieves."

So worded, many different ways of fulfilling its task are left open; it allows for the greatest flexibility. No wonder that outside forces, forces of the environment, have liberally shaped the organization. When the history of TNO started there already existed some institutes of the original governmental type fully comparable to the agricultural advisory stations (e.g. on fibers and textile, heat technology, fire prevention, and others).

The law provides for the transfer of these governmental institutes, including the original agricultural experimental stations, to the TNO organization. In fact a small number were transferred indeed, but others, specially the agricultural ones, were not. There is no question about

actually accepting this as a fact; although up to a certain point one could regret that the unity of all applied research within the domain of government has not been factually brought together under one umbrella. More important, indeed, is to see how the original principles have continued to be valid. When developing more rapidly, TNO saw the fulfillment of its duty to lie in the establishing of research laboratories. Things *could* have been different though. The TNO duty *could* have been the compiling of information through documentation, from within as well as from outside the country, then the digesting of such information and the adapting of it for practical application. On this basis, a system for this bringing ready cooked information to the customer could have been built up.

But actually the choice was made for real *research institutes* and rightly so, no doubt. We must not forget that the cradle of the organization was in the house of science itself, the Royal Netherlands Academy of Sciences. It was science that *offered* services to the needs of the country; it was not society that *asked* for the results of science! In the eyes and minds of the originators, the workshop of science could be nothing else but an institute or a laboratory. Therefore about 35 of these have been established. Working groups, coordinating committees, committees with special tasks, service departments (Mathematics and Statistics Department, Patent Department) and the like complete the list. The total number of TNO employees amounts to nearly 4,000, of which 600 are university graduates. All in all, it is the biggest research unit in the Netherlands.

Potentially all the institutes and laboratories may serve industry in all the variety of its needs. Only a few of the institutes of the Organization for Health Research TNO are practically—though surely and definitely not in principle—hardly in contact with industry. But of course, the Organization for Industrial Research TNO is the main supplier for industry.

This is reflected by the fact that half of the total budget and half of the total number of employees belong to the Industrial Research Organization. To make the picture somewhat clearer I may point to the printed matter I have brought with me.

When industry—and I will now confine myself to this aspect—wishes to have its problem serviced by scientifically founded knowledge, or by some ad hoc scientific research, there are two entries.

Let the case be that of a middle-sized metalworking factory. It should be said—by the way—that in Holland middle size means 100 to 500 employees, of which one or two or eventually three are fully academically trained mechanical engineers. Perhaps from the younger generation of factory owners one, having had full-scale Technical University qualification, may have become a member of the Board. Surely, there will be no research department, but the contribution of the hypothetical three engineers, together with the know-how of the original founder and his devoted foremen, warrant a good and efficiently manufactured product. However, let us assume that the need for some improvement is felt. The manager can then address the Institute for Metal Research TNO or, if he is not quite sure that the improvement will come from some branch of metallurgic research, it may address TNO's central office. This "H.Q." will then pass the question to the TNO institute considered to be the most appropriate. So it does not matter whether the factory manager would either have contacted directly the institute of his choice, or the central or any periferal TNO address. His question will be directed to the relevant place and thus we rightly claim that he who comes in touch with any place in TNO may rest assured that he will have the whole of TNO potentialities behind

his problem. And this may be essential. For, even if his problem appears not to be a metallurgic one, but can better be solved by the use of some plastic, or through protecting metal parts by some paint or other coating, or by chemical surface treatment, he will be shown the way in the TNO network.

Let us assume that the initial consultation leads to the conclusion that some research work in one or two of the institutes may solve the problem. Then the questioner may become a customer in the sense that an order for contract research is agreed. Here the advantageous position of TNO stands out, because the customer will have to deal with no more than one contracting party. For, in its turn, the contracting institute will put out to contract those parts of the problem that can best be tackled by another of the very many TNO institutes.

In every contract there will be some latent partnership of the Government. Without that the solid basis of buildings and permanent staffs of the TNO institutes would never exist at the actual dimensions. There would be nothing of the routine, built up over the years, nor of the selection for creativity, or the high-level equipment, etc., were it not for the initiative of the Government. But there is more:

In case of a contract, a bargaining position is around the corner. The Government cannot be imagined to be the one of two negotiators who sells its services. This capacity now has been entrusted to TNO, for its research organizations are allowed to settle accounts "by requiring payment to be made in respect of research performed for particular persons or institutions or for advice rendered to them." This certainly has been one of the reasons to confer corporate status to TNO, thus making for the responsibilities the Government had accepted in principle.

Still another aspect will have to be brought into the picture. Contract research is a matter of confidence and, not infrequently, of secrecy. This is a managing problem. For a body corporate as such can never be sworn to secrecy. This can only be dealt with by building up a reputation of absolute reliability and of loyalty to the sponsor. I dare say that the organization has done its utmost in this respect; even the conditions of employment of every TNO employee in a crucial position can be completed by a so-called competition clause. But still, unfortunately, industry frequently remains somewhat suspicious and it would be wishful thinking to rest assured that private enterprise would not feel and fear government to be somewhere in the background of its own creation, TNO. This will not be openly said and, if asked directly, the point would be evaded or denied. But the matter-of-fact man knows what's on. The result from all this will be that contract research is a vital relationship between the medium-sized enterprise and TNO, but that it could be expanded and thus be a stronger support for the industry which has a hard job to keep pace with rapid modern developments.

For the smaller on the one hand and for the big industries on the other, the situation is totally different.

For small industries (below 100 employees) of which there still are about 9,000 in our small country, the hard fact is that they do not know—even still now do not know—how to fit science in their shops. Putting the right question is one difficulty. Understanding the answer is another problem. This is a matter of permanent concern. Government and specifically the Ministry of Economic Affairs has an old-established service called Netherlands Technical Consulting Service, of which the terms of reference are to

help industry, especially the small and very small firms, in every feasible respect.

For the 1-to-10 men's workshops it has done an immeasurably good job, as its advices even cover purely financial and elementary managing aspects. A technical workshop with a limited number of mechanics provides for help in troubleshooting. For more complicated requirements, possibly up to the research level, the appropriate part of TNO is contacted. To bring this governmental service under one heading with TNO, or even to incorporate it in the TNO organization, has been considered several times. At some future moment this will—no doubt—be done. Do not forget, however, that a country wrested from the water makes dikes and if they appear not to be strong enough, will make new dikes and let the old exist.

Some 2 years ago in collaboration with OECD, an instruction unit for simple and low cost automation was established by the Organization for Industrial Research TNO. It has meanwhile had hundreds of young mechanics and even polytechnicians as its pupils. It is one of the very few teaching units in the organization; it has had considerable success and demonstrable effect. In these two ways, Netherlands Technical Consulting Service on the one hand and the low-cost automation instruction team on the other, the small industries are serviced through responsibility shared between Government and TNO. In these types of service research as such is hardly in the picture.

The big industries have a relationship to TNO that is fundamentally different. As big industries in this context should be considered the ones that have their own research capacity. I cannot omit pointing to the fact that the Netherlands have a small, but in relation to the nation's dimensions an exceptionally high, number of industries of international scope and size. From these I name five, Philips, Shell, A.K.U., Unilever, and Statemines. Their research capacity is altogether about equal to the total contribution of the Dutch Government to scientific research.[1] I may consider it a known fact that their research is in the van of progress. This is not limited to development of new products and manufacturing engineering; but it holds even more true for fundamental research. Through international exchange, and through their patents and licenses policy, these industries are in the forefront by their own means. Nevertheless 15 to 20 percent of the TNO contract research comes from these industries, a fact that asks for some closer examination.

TNO has built up a very widely branched research capacity. It works together with many scientific authorities and it has been provided by the Government with an aggregate of research equipment—buildings and high-level instruments, apparatuses, workshops, staff, and personnel—that hardly has its equivalent as a coordinated research body in the country. Its coherence guarantees cooperation to the utmost and avoidance of wasteful duplication. From the governmental subsidy, which in the industrial sector is about equal to the yearly income from contract research, TNO's free exploratory research has been supported uninterruptedly for more than 20 postwar years. From this stimulating environment many specialists of high quality have originated. Cooperation with the universities and technological universities is wide; professors are advisers

[1] In 1964, the "Big Five" together spent 428 million guilders on R. & D. and the other industries together spent 289 million guilders.

In the same year, the Government granted 421 million guilders as R. & D. subsidies, of which 80 million went to TNO, 186 million to the universities, and 155 million to other organizations, etc.

to TNO institutes, institute directors or university trained staff members are professors extraordinary to the universities.

Thus an extremely versatile and adaptable research body has come to existence. The bigger industries frequently have their own research bodies, very much specialized in their own industrial fields, may these be ever so broad. Nevertheless, from time to time, not too infrequently as a matter of fact, they come across problems that lie beyond their scope. Many times the complexity of these problems is not to be neglected. To set up a new research department is not justified. Then to meet the needs of the big industries TNO comes into the picture, and at its best. It will then be no exception when two, three, or more TNO institutes work together, a project coordinator being appointed and the best of workers being brought into the project group. In such cases close cooperation can be found possible between two or even three special TNO organizations, for instance Industrial Organization, Defense Research Organization, and Organization for Health Research. Then the original intention of the law is manifested at its best. We thus still find the origin of the organization reflected: it has been science which offered through the mediation of at that time the totally new concept of a coherent complex of research organizations, TNO, the assistance of science to society. It certainly would have come out differently if it had not been science that offered, but society that had asked.

To close my triangular exposé I still have to draw the third connecting line, the one between Government and industry, in the field of research. After what I have already said, it will be clear that in my country this direct relation will not be a very strong and determinating one. Some aspects, however, merit being mentioned briefly.

In the first place the Dutch tax regulations allow an industry to mark in its books as deductible items all costs spent for research, may it be in the industry's own laboratory or in respect of research farmed out for example to TNO. This being so, it is another—though indirect—support of the Government to industrial research efforts and this accounts partly for the rather high priority that research has in my country.

Along with the increasing trend of international thinking it has not remained unobserved that especially the United States have a system that could almost be called the diametrical opposite of the Dutch pattern. Government-sponsored research in your country is frequently, or so to speak even preferably, entrusted to the big and biggest companies. Their research capacity was at hand in the years of the extreme effort of World War Two. It had to be used, that is: it had as quickly as possible to be translated into practical application and, after a rapid development, brought to bear upon production. This has led to enormous expansion of the research capacities of many companies; the bigger ones among them even have transformed their research groups into independent research corporations, receiving astronomic amounts out of the Federal research contracts. This has created the unprecedented scientific leadership of your Nation. Could this fail to make a deep impression on any country which feels the importance of research for promoting its standards of life?

No wonder that the Government in my country, learning from your system, considers to award contracts to existing research departments of industry. In some cases, when special experience exists in these departments, doing so is fully justified. But to me as a leader of the TNO organization, it causes great concern. Research is, apart from being

a matter of money, frequently much money, a matter of men and of built up experience. If this granting of Government contracts to industry might lead to extension of its research capacity, it will mean that the Government enters into competition with the research body it has created itself. This is harmless as long as means are freely available. But all over the world the phenomenon of some kind of saturation of research effort is in the air, be it from the financial, the manpower or the purely psychological point of view; of course the level at which this phenomenon presents itself is utterly different in the different countries. Under these conditions for my country it would mean an enormous waste of capacity (again financial and of manpower) to induce new research activities, instead of making the existing ones as strong as possible. There can be a danger in taking over the system of others. Duplication, the not unusual phenomenon in research of exploring anew the well known, and also the doubt whether the results can be really applied for the community, threaten around the corner.

One could continue to illustrate many more aspects of the triangle of interaction, draw other lines of connection.

This is especially tempting when one is enthusiastic and yet full of concern about the setup to which one devotes one's daily work.

Let me conclude with one short statement.

Appreciation for one's own system should never cause blindness to its failures. I have sketched in my best possible way how our own TNO organization works. However, I can assure you that no one knows better than I do how it *should* work to render even better service to one of the most vital elements of my home country.

MODERN EVOLUTION OF SCIENCE AND TECHNOLOGY IN JAPAN

Kankuro Kaneshige

I do not at all pretend to be an expert in economics, and I may be stating facts already known to many of you here, but I shall begin by mentioning some often-cited figures from statistics on Japanese economics, to have before us first of all an idea about the kind of rapid growth achieved in recent years by the country I am going to speak about. The yearly growth rate of the gross national product in Japan—after correction for price inflation—has been 12.8 percent in 1963, 9.9 percent in 1964, and 4.3 percent for 1965 (based on preliminary reports published in September 1966). The average growth rate for the 10 years from 1956 to 1965 has been 11.5 percent.

It is frequently said that Japan set out on its way to modernization after the Meiji Reform of 1868, to reach the present state of industrial development in less than a century. This is believed in general by many of my own countrymen as well as by foreigners. I for myself do not fully share this interpretation, because I think it only holds true when the term "modernization" is taken in the narrow sense of "westernization," which in effect started around the Meiji Reform. You will agree that a rapid and successful industrial revolution is not set off overnight on unprepared barren soil.

History tells us that it was about 15 years before the Meiji Reform that construction was started on a shipyard modeled after Western practice, and that in 1857, that is 11 years before the Reform, Western steelmaking methods were already introduced into Japan. Thus one might even say that Japan *continued* to import and assimilate Western technology *despite* the upheaval of the Meiji Reform rather than as a consequence of it.

Looking further back in the history of Japanese industry, we see that the beginnings of modernization can be traced to a surprisingly early period. Taking as an example the art of shipbuilding, it is known that, to carry the missions sent to the Chinese mainland nearly a score of times between the seventh and ninth centuries A.D., the ships were each time built in Japan by Japanese hands. About the year 1605, an Englishman named William Adams is known to have directed the construction of two Western-style ships, one of 80 tons burden and the other of 100 tons. This historical event was followed in 1638 by a decree forbidding traffic abroad, and no more seagoing ships were allowed to be built for the next 215 years. Soon after the ban was lifted in 1853, shipyards planned according to Western design were being established in places like Nagasaki, Yokosuka, Uraga, and Ishikawajima. I mention these localities because you may recognize their association even today with the names of still existing shipyards and shipbuilders.

The standard of Japanese naval architecture can be considered to have attained equality with Western powers in the early 1940's, when the completion of two monumental battleships, displacing 69,000 tons each, marked an epoch in the country's shipbuilding history. It is not my

purpose today to give you an account of how, later, the Japanese shipyards recovered from the destruction suffered during the Second World War to gain their present position in the world, nor to try to explain how it was done. What I want to emphasize is the opinion I share with Japanese shipbuilders that the status they have gained today is solidly based on tradition and experience, backed by an army of qualified and competent engineers and technicians ready to apply the most advanced practices.

The methods and techniques utilized today by the Japanese shipbuilders in constructing their ships have not originated in Japan. For instance, the practice of welding hull plates, and its application in building up the hulls from prefabricated blocks, are both techniques conceived and employed in the United States during the last war and later developed in Sweden and Germany. The Japanese shipyards, in assimilating these new techniques soon after the war, went about it with particular thoroughness, by applying concerted efforts to overcome the problem of cold brittleness of welded hulls, and by almost completely realigning their shipyard layouts to bring out every advantage that could be exploited from the new system of welded block construction.

Beginning about 1960, ultramodern facilities conceived for building super-mammoth tankers and bulk carriers began to be constructed here and there in the country, and some of these new yards were operating already at the end of 1964. One of them produced in January last year what was then the largest tanker in the world—the *Tokyo Maru* of 151,000 tons deadweight. This was followed only 10 months later with the *Idemitsu Maru*, bigger by more than one-third, and the present record holder for size.

One of the most notable achievements of Japanese shipbuilders is their success in shortening shipyard time. In 1952, a tanker of 20,000 (deadweight) tons took 12 months to build; today, 15 years later, her sister of 10 times the size is finished in 10 months. The *Tokyo Maru* had her keel laid on May 6, 1965, was launched on September 27, and delivered on January 31 of the following year; the very next day—on February 1, work was started on the 209,000 (deadweight) ton *Idemitsu Maru*, which was launched on September 4 and completed on December 7.

A second point of pride held by Japanese shipbuilders is the amount of automation incorporated in the ships they build. Some of you may smile to hear me talking about Japanese automation in the country where automation was born and bred. But as far as automation in ships is concerned, I think I may state in all truthfulness that at least the Japanese engineers and shipowners are as eager in exploiting it as any of their foreign colleagues. As evidence, the high-speed cargo liner *Kinkazan Maru* completed in 1962 has a complement of 43 where 50 would have been required for the same ship without the automation systems built into her. A ship of the same class designed today would be staffed by not more than 36, and there is a record of 28. In the case of tankers, 60 people were required to operate a 75,000 (deadweight) ton tanker in 1960; today, the number would be only 31. The *Tokyo Maru* mentioned before, is manned by a complement of 29, and the *Idemitsu Maru* has only three more people aboard.

Let me briefly cite just a few more accomplishments of Japanese naval architecture: Studies to improve hull form have reduced required engine power by as much as 25 percent in one instance; efforts to economize steel consumption per unit ton have in one case cut the figures down by 30 percent between 1958 and 1963; and in another instance the man-hours deployed per unit ton of work have been reduced by as much as 60 percent in the same interval.

I have said all this in an attempt to prove to you that the Japanese shipbuilding industry has won its present position, not with pacemaking innovations, but through the accumulated efforts of their engineers, who have added one little improvement to another in untiring succession. And the engineers have been ably backed by a trained and qualified staff at all levels of production, capable of putting into effect the improvements planned by the engineers. And we must also recognize the part played by shipyard management with their timely decisions to improve their facilities and equipment, and their determination in seeing their plans carried out.

Turning now to other Japanese technical achievements based on effective application of existing knowledge and methods, I might mention the New Tokaido Line providing the fastest rail service in the world. This railroad was opened to traffic in October 1964, and it was followed by a number of early troubles that stopped trains in between stations or prevented doors from opening at the stations, and other mishaps of that sort. It was one of the students I had taught 30 years ago who was in charge of the railroad at the time, and he showed himself fully capable of dealing with the situation and getting all the bugs out of the system one after the other: Today, this service hardly ever figures in the news—which means that over 60 runs in each direction are being maintained day after day without mishap almost exactly according to timetable.

The Japanese National Railways have also developed a computerized seat reservation system they have named MARS. You may of course know that similar devices have already been used for some time by airline companies, but I have been told that MARS incorporates many advances over previously known systems: It has a memory covering a million seats and sleeping berths on connecting services, and can handle an unprecedented variety of problems like inquiries for a specific seat on a specific train, or searching for vacant seats in blocks of up to four occupants in a group. The output units of the MARS network, located in the individual stations served by the system actually print the tickets with all the necessary information about the seats reserved, and don't even forget to type out the price to be paid by the customer. When I heard a railroad official explain to me all the tricks that can be done by MARS, my comment was that it's all very fine to be able to process reservation tickets in a matter of 30 seconds from a choice of 1 million seats, but if in future even this number proves to be insufficient, it might be time to start thinking of improving the train service itself so that fewer travelers would feel it necessary to book in advance to assure themselves of a seat.

It is generally known that Japan is not blessed with abundant natural resources. For instance, the country has to import 90 percent of the iron ore it needs for steel production, and almost 100 percent of its coal—insofar as concerns the strongly coking variety required for blending in blast furnace charges. And with all this importation of raw materials, Japan has become the world's third largest producer of crude steel, and has exported nearly 10 million tons of steel and steel products during 1965.

I am now going to spend some time on this paradoxical Japanese industry, because I think such a description should help in bringing out some revealing aspects of the country's industrial and technological organization. Here again the primary factor that has contributed to industrial growth has been the energetic programs successively carried through for optimizing production facilities. These projects for plant innovation were aimed at

exploiting to the utmost the newest processes available for producing steel with the least cost and labor. Their success is witnessed by the sharp drop seen in such indexes as coke ratio: In 1956, Japanese blast furnaces consumed 725 kilograms of coke to produce a metric ton of pig iron; in 1965 the average coke ratio was 507 kilograms. This is, as far as I know, lower than any other national average in the world.

One factor that has contributed perhaps more than anything else in assuring the competitiveness of Japanese steel in the world market is the practice of using pure oxygen for steelmaking, with the equipment known as the LD converter. The original system was introduced into Japan from Austria fairly early after the war, but it saw appreciable development in the country of adoption, with improvements such as better lining refractories, the multinozzle oxygen lance and new methods for recovering waste gases, all of which enhanced the economic advantages of this system. By mid-1964, one-third of the world's LD-type converters were operating in Japan, which topped all other countries in capacity for steel production by this system. This title was, however, ceded last year to the United States. Records indicate that in 1965, 55 percent of all crude steel produced in Japan came from a pure-oxygen converter, and this fraction is expected to increase further.

The Japanese steelmakers have until today imported many of the most advanced processes and methods to improve their equipment. They have recently begun to repay some of their acquired knowledge by reexporting improvements made on the imported technology. Examples are seen in new processes for recovering converter waste gas and for producing rustless steel sheet by chemical treatment. One Japanese steelmaker has announced that the firm is now receiving more than it pays in royalties for licenses.

Such cases where exportation of Japanese technology is beginning to balance imports is of course a rare exception, and Japan is still leaning heavily on foreign licenses for modernizing its industry. The sum of license fees paid abroad has totaled an equivalent of $166 million in 1965, while corresponding receipts were only $13 million, or 7.7 percent in proportion. That something should be done about this unfavorable balance has been the subject of concern in Japan for some time.

In 1958 the oldest university in Japan celebrated its centenary jubilee. The Japanese university system is of course far younger than in some of the Western countries. In the domain of primary education, however, there existed in Japan, even before the Meiji Reform, an institution for teaching the "three R's" to children. About 10,000 schools, in their rudimentary form, are known to have existed on the eve of the reform, run mostly by Buddhist priests in the temple precincts. In more advanced domains of learning, it is known that a mathematician by the name of Seki had already conceived the principles of differential and integral calculus in the 17th century during the period when the country was cut off from foreign contact by the self-imposed embargo mentioned earlier. After the Meiji Reform, the government devoted much of its efforts to the extension and promotion of education, in line with which it enforced compulsory education in 1886. Today, Japan is a nation of decidedly education-minded people, with parents determined to sacrifice everything to get a good education for their children. This trait is well reflected in statistics which reveal that the country is third in the number of students receiving higher education, compared on per capita basis, despite its not even figuring among the 20

topmost nations in respect of per capita income. The immense potential manpower of educated population thus formed is what I believe to be the strength of Japanese industry. But why the brains available in such abundance are not directed toward more inventive activities in creating original technology is a point that should provide much food for thought among us Japanese.

Your attention may perhaps have been drawn to the statement contained in an OECD report entitled "Review of National Science Policy, Japan" which pointed out a deficiency seen in effective coordination between the three categories of organizations associated with research and development—the research institutions, including the universities; industry, constituting the beneficiaries of research and development effort, and the competent branches of administration. I regret to find it rather difficult to refute this observation. An American friend of mine, who visited Japan in 1957 to attend the 10th anniversary celebrations of a scientific society I was heading at the time, wrote upon his return in a report: "I detected a serious obstacle which the Japanese must overcome quickly—a lack of cooperation between industry and institutions of higher learning. Industry feels that colleges and universities are too theoretical in their approach to problems, while on the other hand the schools believe that industry is too materialistic, and unwilling to pay for brainpower." The situation might be considered to have improved to some extent in the intervening years. But remarks so coincident in substance coming from independent sources would appear to point toward a rather evident weakness in Japanese training, and a remedy must be found by ourselves in Japan.

In the beginning of the Meiji period, an appreciable number of professors were invited by Japanese universities from abroad. Some of them later returned to their own countries to become eminent scholars in their fields. Others came to appreciate sincerely the country and the people that had received them, and they stayed to teach all their lives. I think it extremely fortunate for the Japanese universities to have received the assistance of such good teachers.

Fostered by these and other favorable circumstances, the universities in Japan grew and developed. In 1879 there was established an institution that later became the Japan Academy. The National Research Council was set up in 1920. And in this manner the Japanese academic system gradually took a form following the pattern of the Western countries. This, in turn, fostered communication and exchanges with the advanced world centers of learning.

In time, the country came to produce the Nobel Prize winners, Yukawa and Tomonaga, as well as other internationally famed scholars like Honda and Mishima, known for their work in magnetic alloys. But here again, the original formulae discovered for producing supermagnets had to be further developed in Western countries before being reimported by Japanese industry to be put to practical use. I know of other cases of such inconsistent breaks in the chain of research and development, which must have prompted the observation I quoted earlier from the OECD report. Such a weakness, apparent even to foreign observers, has of course not remained unnoticed by those concerned in Japan, and they have been seriously discussing what might be done about the situation. But it takes time to establish a really effective bridge of communication between academic and industrial circles in a country where these two communities have independently developed by absorbing Western ideas and practices

with no contact between each other except for the supply of qualified manpower. It would appear that both university and industry have found inspiration forthcoming more readily from their teachers abroad than from their Japanese neighbors.

Soon after the Second World War, the view was strongly voiced in Japan that the scientific mind should henceforth pervade all our actions. We termed this way of thinking "scientification". We felt that this newly fashioned word very nicely expressed our conviction that the voices of scientists should in the future be much more strongly reflected in national policy. The ways and means of bringing this about were deliberated among the members of an ad hoc Renewal Committee for Science Structure, and, in conclusion, it was decided to replace the National Research Council by a new Science Council of Japan. All this occurred during a period when the country was under Allied occupation, so it was natural that such reorganization could not have been realized without the understanding and encouragement of the occupation authorities. For this reason, I think there are many in Japan who still believe that the present setup is not a Japanese brainchild. It may not be correct to deny outright the foreign influence that played its part in this reorganization, since I would find it difficult to assert that a similar feat could be accomplished today in a completely independent Japan. Nevertheless, it is a fact that the blueprint for the reorganization was drawn up by the members—all Japanese—of the Renewal Committee; and I have reason to know this, because I happened to be chosen chairman of that same committee. The official in charge at the occupation headquarters, to whom it was my duty to report on progress every month was Dr. Harry C. Kelly, who is now dean of the faculty in the North Carolina State University at Raleigh. And 10 years later, in 1961, Dr. Kelly and I were brought together again a cochairmen of the United States-Japan Committee on Scientific Cooperation. We have been serving in that capacity ever since.

With my apologies for digressing into my personal recollections, let me go back to the Science Council of Japan, which was duly established in 1949 to represent and defend the views of scholars, scientists, doctors, and engineers of the whole nation. Many of the resolutions and recommendations submitted by the council to the government have been put into effect, including the foundation of a number of research establishments such as the Institute for Nuclear Study. Opinion is divided as to whether the Science Council's activities have fully answered expectations, since everyone is free to appraise the achievements of an organization from his own standpoint; and elements of truth are probably shared by both sides, in that the body has amply fulfilled its function in some areas but fallen short of expectations in some others.

Turning now to the role played directly by the Japanese Government in research and development, the Ministry of Education has, since the earliest days, taken upon itself the task of promoting academic research in universities. Other branches of government have independently set up research establishments to suit their own needs as necessities arose. One of the oldest is the Electro-Technical Laboratory established in 1891. Nearly 80 similar institutes are now owned and operated by the different administrative branches of the government.

For the purpose of coordinating the efforts of these various government research organizations and to enhance their activity as a whole, a new branch of government named the Science and Technology Agency was established in 1956, with a Minister of State designated as Director General.

This was followed in 1959 by the appointment of a Council for Science and Technology to advise the Prime Minister in setting up basic national policies for promotion and encouragement in the fields of science and technology. The council has submitted five reports to the Prime Minister during the seven years since its establishment. How well the Council has done its work so far is again a matter of opinion: Possibly, many Japanese scientists would not hesitate to express their disappointment. Government officials would probably be keen to defend their efforts in overcoming the odds against them. As for myself, having served as council member at the time of its establishment in my capacity as president of the Science Council of Japan, and for the past year and a half as one of the two full-time appointees, I feel myself incompetent to speak either for or against this organ of government I am at present serving, however small my contribution to it may be.

I will end my talk here. We shall have to leave it to the historians to judge the success or failure of the past policies governing science and technology in Japan. But I would be more than happy if I have been able to put across to you some of the serious efforts that have been undertaken in Japan to improve our status in this field since the end of the war.

SCIENCE AND TECHNOLOGY AS EMPLOYED IN THE DEVELOPMENT OF A NATIONAL ECONOMY

Robert Major

What makes this such an unusual pleasure is that our host, the Committee on Science and Astronautics, is the most active parliamentary science committee of today. Parliaments are in many countries a brake to scientific development—we have seen how Congress, with this active committee, has become part of the motor bringing science to bear on the future in this country. We do all look forward to spending these days with you, and under the theme of this panel meeting I think it will be most relevant for us and of great interest, when we return to our countries, to inform our parliaments about the work of the committee.

In my paper I will try briefly to describe how science and its application influences our life, and point out how slow most countries have been in developing a national science policy with a view to achieving a maximum utilization of science and technology for national goals, and some of the reasons for this. I will mention examples of international cooperation stimulating the creation of national science policies and describe as a case study endeavors to develop a national science policy in my own country.

Through development of mathematical, chemical, physical, and biological disciplines, an ever-growing reservoir of knowledge has been created which, through application in industry and other activities, continuously changes our way of life.

Science and the application of its results has formed the basis for development of modern industry and created an ever-expanding spectrum of new goods for consumption and production which completely have changed the structure of industries: It has made possible effective exploitation of the various sources of energy for many purposes; it has led to development and changes in agriculture, forestry, and fishery which have greatly increased the production per person employed; it has made possible a development of building and construction activities, which has raised the standard of housing and made possible constructions of completely new character; it has formed the basis for the development of modern communications, which have opened up entirely new possibilities for transport of personnel and goods; it has led to the development of telecommunications, binding together people all over the world; and it has made possible the development of modern medicine and health service which, with the factors mentioned above, have given basis for the high social standard of our days.

Considering the important tool that science and technology has become, not only for economy and welfare, but also for strength and prestige of nations, we might have expected many nations to have devoted more of the energies and resources to strengthen their position in this field.

It took, however, considerable time before the role science and technology play in the development of society was understood. Today this

role is, I think, generally recognized, but the whole process of how science and technology can be fostered and brought to bear on important national problems is as yet in most countries little understood, or at least not common knowledge.

The reason why the establishment of strong and well-considered science policies in most countries do not advance with the speed we might expect is, I think, to a great extent due to the fact that the general knowledge of all the factors which build up such a national policy has not yet reached a sufficiently high standard in a wide enough circle. Another reason is probably that as the building up of research and development activities is a long-term process, which usually gives yields in a somewhat distant future, it may not always, under prevailing political systems, attract sufficient political support. This will, of course, depend upon the national goals, and to what extent science and technology is involved in them.

The development of new knowledge and the efficient use of this knowledge for the development of society demands, as we know, an educational system turning out a growing number of highly qualified people and well-equipped research institutes in universities, government, and industry, giving bases for the growth of what we call the scientific community. But the work performed by this community will not give maximum effect for the national needs unless there are people in government, in industry, and in research organizations who are both familiar with the national problems and needs, and who also understand how science and technology can be used effectively to solve the national problems.

There must be an interplay between the scientific community and the leading people in government and industry which, on the one hand, make sure that research capacity is developed and used effectively for the national goals and, on the other, keeps government and industry informed of new knowledge which may influence their problems and planning.

In most countries it seems to be easier to build up a system of institutions with academic competence in the various disciplines than to create a general ability throughout industries and administration to utilize science and technology effectively and wisely to meet industrial or other national needs. It seems, in a way, to be easier to build up a tool than to use the tool efficiently to solve relevant industrial or national problems.

I would not say whether this generally is the fault of the scientific community, of industry, or government—we just have to observe, I think, that in most countries much could be achieved through a closer relationship to which all parties must contribute.

The knowledge of these problems and the development of a national science policy has reached very different stages in various countries, and much can be achieved through exchange of information among countries.

Most of the countries advanced in this field are now members of the Organization for Economic Cooperation and Development (OECD), and this organization has now become, I think, our most outstanding international center for the study of science policy problems. Delegates from member countries form three committees—one for scientific and technical personnel, one for research cooperation, and now recently also one for science policy. They have studied topics relevant to national and international science policy and produced a number of valuable reports. Topics covered are, among others, the demand and supply of scientific and technical personnel in member countries; the role of science and technology for the economic growth; government's role in the stimulation of technical

innovations; government allocation of resources to science, et cetera. The Directorate for Scientific Affairs of the OECD has been developed to an excellent secretariat for these studies, and the OECD has become a very stimulating forum for the exchange of knowledge on science policy problems.

An interesting exercise of the OECD is the country reviews of science policy in member countries which are now being carried out. Country by country are being reviewed by internationally recognized scientists and research administrators and valuable experiences exchanged. The review of the United States is at present in progress. Every second year ministers for science are called together to discuss important science policy topics. It has added very much to the strength of this milieu that the United States now, after the reorganization of the OECD, has taken such an active part in these activities.

One of the topics studied in the OECD forum is the role that science and technology play for economic growth. Many reports have been produced on this topic, not least in this country, and several attempts have been made to express in percentages how much of the economic growth is due to new knowledge and new ideas; that is, to education and research.

Up to 40 percent of the economic growth has, in some of these studies, been attributed to these two factors. Personally, I believe that the contribution of education and science is too much interrelated with other factors to allow for precise calculations.

These studies have, however, no doubt been very valuable because they have illustrated not only for scientists but also for economists and politicians that the role of science and technology for economic growth is considerable.

The problem of size is rapidly becoming a serious problem, specifically for small nations. In a growing number of research fields the minimum threshold value for realistic activities has now become so high that smaller nations and firms only can take part through the establishment of international cooperation. We know this from big science, where the European countries have joined forces in high-energy physics and space research We also know it from new technological fields such as construction of big computers where the technology for development, production, and sales has become so complex that only a few companies in the bigger countries seem to survive.

This brings us to the problem of the technological gap, which is now so much debated. There is, no doubt, a gap, but I am not so sure that the basic reason for it is lack of scientific and technological activity in Europe. Many examples can be given where European countries have been leading in science and technology, but nevertheless lost the production race. I think the reasons for the gap is more the difference in mentality and attitude, managerial skill, and markets. I think on this side of the Atlantic you are more dynamic, more geared for the future, and have established a management skill which, with a big home market free of customs barriers, has been essential for the creation of big industrial units. We have had science and technology in Europe for many years, but what we lack is a more dynamic attitude and the establishment of a common European market which will make possible the creation of more big industrial units. Scientific and technological activities could easily be expanded in Europe if there were industrial management and government administrations capable of making better use of them.

The nature of the gap will now be the subject of a comprehensive study in the OECD. This will comprise detailed studies of eight particular

industrial sectors and other relevant studies with a view to pointing out differences on either side of the Atlantic. The object of this study is to clarify reasons for the gap, which can form the basis for discussion of possible remedies. Whatever conclusions this study will lead to, it will no doubt throw considerable light on the complex of factors which make science and technology effective tools in the development of the economy of nations.

As a sort of case study to illustrate an attempt to develop a national science policy, I will mention a research report which has recently been made in my country.

Based on certain discussions regarding the role that atomic energy research should play in our overall research picture, the Parliamentary Committee dealing with industrial questions asked sometime ago for a report giving a survey of all national research efforts in the scientific and industrial field, with suggestions for future activities.

This request was from Government passed on to the National Research Council for Scientific and Industrial Research, which is a semigovernmental organization charged with the task of promoting and coordinating scientific and industrial research, and now controlling approximately one-third of all scientific and industrial research activities in the country. The council saw this request as an opportunity to present to government and Parliament a report which could form the basis for the development of a national science policy for the fields covered by the council; that is, research for industry, shipping, building activities, transportation, and so forth.

Important as it is to have a good plan, it is equally important to be able to realize in practical work the plans you agree upon. To mobilize already at an early stage the people who would be engaged in the realization of the plan, and make them feel the plan as their own, more than 200 outstanding people from government, trades, industry, and research were engaged in 22 subcommittees working for the report. They covered the various branches of trades and industry, and also some special fields like automation, atomic energy, and pollution.

These subcommittees prepared reports on their particular branch of trades and industry, describing its role in the national economy, its technological status, future prospects, the needs for research, and the new possibilities research activities could open.

The report has three main chapters:

There is first a survey of research activities and its organization in Norway and other countries.

Secondly, there is an analysis of the various industries and other national activities in Norway with a view to identifying their research needs.

Thirdly, based on the findings, there is a chapter with recommendations and suggestions.

The analysis of research activities of the country showed that the overall research and development volume had increased more than sixfold since the last war. One of the striking features was, however, the relatively low research activity in industrial companies compared to the overall activity. Only about one-third of all research and development work was performed in industry, whereas industry's part in this country is approximately two-thirds. The absence of R. & D. contracts in the military, space, and atomic energy fields, and the existence of relatively few big industrial companies, was mentioned as important reasons for this relatively low activity.

Although progress in research and development on the whole has been good, the overall volume was still less than 1 percent of the GNP and did not

compare too favorably with other industrialized countries. As you know, the United States now spends approximately 3 percent of its GNP for R. & D. activities, and although statistical material from Soviet Russia is not quite comparable, it is reasonable to believe that they spend about the same percentage. According to the latest information from the OECD research statistics for 1963, Great Britain spent 2.3 percent of its GNP. Three countries—the Netherlands, France, and Japan—spent between 2 and 1½ percent. Sweden, Germany, and Canada spent between 1½ and 1 percent, and Belgium and Norway a little below 1 percent. An analysis of these figures shows that in practically all the countries mentioned the percentage spent by governments on civilian research and development was about the same: approximately one-half of 1 percent of the GNP. The high overall percentage in some of the countries is thus partly due to high R. & D. expenditure in the fields of defense and space, and partly to higher expenditure by industry.

It is interesting and useful to see what other countries do, but what a particular country should spend must mainly be determined from its own national goals, and its capability to absorb greater activity in its own structure. In the report, we therefore analyzed our own trades and industries to clarify the role that research and development could and should play in the various sectors. For this study, the reports of the subcommittee were extremely useful.

The manufacturing industry, which contributes to the GNP with approximately 25 percent, is to a great extent based on our own raw materials with a comparatively little processing degree. Except for waterpower resources and possible discoveries of gas and oil in the North Sea, we do now exploit fully our resources of raw materials, and it was pointed out that a further expansion of our manufacturing industries must be based on utilization of know-how and will, to a great extent, have to comprise talent industries.

A characteristic feature is the importance of shipping. We have now approximately 10 percent of the commercial world tonnage, which contributes to the GNP with about half as much as the manufacturing industries. Whereas previously sailorship and commercial ability were the dominant factors for shipping, it is now recognized that the use of technology will be a decisive factor in the competition. We have to compete with shipping, which, to some extent, is subsidized, and it was pointed out that a rapid exploitation of technology will be a condition for economic survival for our shipping.

An analysis of the building and construction activities showed that it constitutes an important factor in our economy. The forthcoming change of structure toward greater industrialization will facilitate introduction of new technology, whereby productivity can be significantly increased.

Transport absorbs a big part of our expenditure, but has a low degree of rationalization. It was pointed out that economic investigations and technical improvements could reduce costs and improve transport operations considerably.

The future role of automation and use of electronic data handling in planning, production, and administration was emphasized, and a rapid expansion in the building up of know-how was recommended.

Lower priority to atomic energy research than hitherto was recommended, partly because of the resources of cheap water power, and also due to industry's hesitation to engage in production in this field.

Finally, I would mention that it was strongly recommended to strengthen our competence in a field which does not add to our economy or standard of life, but which is of rapidly growing importance for our well-being: the field of pollution, which has been mentioned earlier today.

In a country which, both in area and population, compares with an average State in this country, it was necessary to establish certain priorities, and the report points out the following fields as being of particular importance:

1. Activities stimulating the production of new machinery, equipment, and apparatus, particularly where production could be based on consumer experience in the country.

2. Activities in fields where we could base production on raw materials or already established competence, such as shipping and shipbuilding, the electrometallurgical and electrochemical industries, and fish processing.

3. Building and construction activities and transportation, which contribute considerably to the GNP, and where increased research and rationalization should add to the quality and reduce costs considerably.

Based on the studies, the following recommendations were made:

1. As quality and quantity of personnel for research and for the exploitation of research results are essential, the plans for improvement and extension in the education sector should be vigorously pursued, and greater importance should be given to keeping curriculums geared for the future, and to the encouragement of creativity of the students.

2. Fundamental research activity, which has its cultural value in itself and forms a necessary basis for higher education and for the creation of a vigorous milieu for applied research, should be strengthened, and particular attention should be given to disciplines supporting fields of applied research which are important for national goals.

3. To encourage greater research activity in the industrial companies, the following three suggestions were made:

(*a*) The establishment of a development fund, functioning as a risk bank to give up to a 50-percent loan to companies for the financing of development projects. This fund is already in operation, with a starting capital corresponding to approximately 25 percent of industry's annual R. & D. expenditure.

(*b*) It was further recommended that technical agencies of the government, in their purchasing procedure, should use research and development contracts to Norwegian industrial firms to strengthen their competitiveness in fields where national production should be encouraged. This is meant to compensate to some extent for the stimulation given to industry in many countries through R. & D. contracts in defense, space, and other fields.

(*c*) Third, it was recommended that the Research Council, which so far has spent its money mainly through research institutes, should also be allowed to give research contracts to industrial companies or groups of companies to build up national technical competence in important fields.

4. A special chapter was devoted to cooperation among research, industry, and government, for the exploitation of research results. It was emphasized that knowledge is not useful for the economy until the educated personnel learn how to use it in practical life, and that research results have no economic value until they have been built into processes and products which are being sold. The need for bridges between research, trades, industry, and government, as I have already described it, was made a key point in the report.

5. In a small country, only a fraction of the new knowledge needed will be developed in the country itself. A strengthening of the technical information service was therefore recommended. In the same way international research cooperation, both at the institutional, industrial, and national level should be encouraged whenever this is a rational way to achieve results.

The report finally discussed the volume of research activities based on the evaluation of the possibilities that increased research activity opens. It suggests that research activities should be given a new dimension. The speed with which we can move will first of all depend upon the ability of industrialists and administrators in government service and research organizations to identify the important problems and to use research to solve them, and further on the supply of really competent team leaders for research projects. Considering the possibilities ahead of us, we must decide to transfer a greater part of our investments from the material to the immaterial sector, and the speed should not, at least at the present stage, be limited by lack of economic resources.

After having viewed the whole situation, it was suggested that investment in research and development activities would have to be doubled over a 4-year period through higher contribution both from government and from industry. This increase in R. & D. expenditure would take about 2½ percent of the calculated growth of the GNP in that period.

An important feature in the report is, I think, the demand for greater harmonization of our research policy to the national goals, to the policies in the various sectors of trades and industries, and other activities. This calls for better planning and coordination, which we now endeavor to implement.

The report has been favorably received by the various industries and trades, and by government, and will come up for debate in Parliament in the near future. It represents a step, and I hope an important one, in the establishment of a well conceived and coherent national science policy.

To sum up, I would recommend—

1. That more emphasis should be given to the understanding of the elements of a sound national science policy.
2. That more energy should be devoted to the implementation of science policies geared to the national goals.
3. That the international aspect of science and the need for cooperation among nations in the scientific field should be taken duly into account as part of their science policies.

MEETING NATIONAL NEEDS THROUGH SCIENCE AND TECHNOLOGY

S. Husain Zaheer

India had scientific traditions in the ancient and medieval periods. However, in spite of the existence of considerable scientific and technical potential, there was, due to historical reasons, a sharp break with earlier traditions in the growth of modern science. The limited growth of science in India before independence, therefore, has been without any deep roots in its history and in its society and its organization was patterned more or less on the "heroic concepts" of the 19th century based primarily on those of the United Kingdom and superimposed on the traditional and individualistic "guru and chela" (teacher and pupil) traditions of Indian society.

Since independence, there has been a major growth and, considering its limited resources, a comparatively substantial investment in science. A major problem in India, like in other developing countries, is the urgent need for a change in the outlook of scientists themselves toward society and of society toward science and scientists; i.e., the problem of integration of science and technology with society in order to remove its isolation as a foreign imposition. Science can no longer be looked upon merely as a bundle of various intellectual disciplines or isolated fields of specialization and a new awareness of the wider role of science and technology has got to be developed in order that science and technology may play their proper and due role in the economic, social, and political development of India in the same manner as science has done in other economically and socially more advanced societies. Consequently, there is an urgent demand for evolving a new era of science as part and parcel of the new society in India fully integrated with and not as an exotic imposition developing only under the impact of influences from other countries; i.e., the emergence of a new image of science freed from outdated and obscurantist traditions and recognizing its universal and international character. Progress toward this ideal is necessarily slow—being hampered by a large number of social and political factors.

The role of science and technology as a crucial element for social and economic progress and development was realized by the leadership of the country a decade before India attained independence. As early as 1938, the Indian National Congress appointed a National Planning Committee under the chairmanship of Jawaharlal Nehru who invited leading scientists, economists, and educationists to participate in the formulation of plans for economic development and social betterment. A study group was appointed to deal with the problems of general education, technical education, and scientific research. Besides other recommendations, this group specifically recommended that the programs of educational and industrial developments should be closely linked with the programs of scientific research. In addition, Jawaharlal Nehru always emphasized the great importance of the development of a scientific outlook—"Scientific temper,"

as he called it—so that science and technology could be integrated as an essential part of Indian society and used without hesitation or reservation for the solution of the problems facing the country. Immediately on attaining independence India embarked on an active program for the development of science and scientific research in the universities and other institutions of higher technology as well as the establishment of a chain of scientific and industrial research laboratories. The great importance attached to scientific research by India after independence can be judged from the fact that already in 1947 India was the first country in the world to set up a Ministry of Scientific Research which was included in the portfolio of the Prime Minister. It may be added here that although India was the first to establish a Ministry of Science and Scientific Research, an example which was later followed and is being followed by many other countries—the Ministry of Scientific Research was eventually abolished in India in December 1963 and the work merged with the Ministry of Education, a step which was generally considered a retrograde by a great majority of Indian scientists, especially of the younger generation.

In 1958 the Government of India adopted the scientific policy resolution (app. I) to define the role of science and scientists as a matter of accepted state policy. The authorship of the resolution is attributed to the late Prime Minister Jawaharlal Nehru himself. The resolution is a guide and beacon in the formulation of state policy and programs toward science and scientists and the utilization of science and technology as instruments of social, economic, and political development as well as its being a charter of the rights, status, and obligations of scientists in Indian society.

Before giving some data regarding investment in science and scientific research in India, it would be desirable to briefly touch upon its present organizational setup.

The organization of scientific and technological research in the country could be grouped broadly under the following six major heads:

I. *Councils.*—(i) Council of Scientific and Industrial Research; (ii) Indian Council of Agricultural Research; and (iii) Indian Council of Medical Research, receiving their grants directly by parliamentary vote through their parent ministries.

II. *Universities and higher institutes of technology.*—These are supported by grants from—

(i) University Grants Commission;
(ii) Board of Technical Education; and
(iii) research councils.

III. *Atomic Energy Commission* established in 1955–56 and now consuming nearly one-third of the total expenditure on scientific research. The main function of the commission is the development of atomic power, besides fundamental research on nuclear physics.

IV. *Defense research and development* under the Ministry of Defense.

V. *Research laboratories under various ministries* or their departments mainly attached to public sector production units or operating departments like railways, communication, civil aviation, iron and steel, fertilizers, etc.

VI. *Research supported by industries or endowments* and receiving substantial grants from the Ministry of Education.

Table II is the broad breakup of expenditure on scientific research classified according to sectors.

It may be mentioned that each organization functions with varying degree of autonomy under the aegis of the parent ministry. The scope and func-

tions of each organization are well defined. The budget for each organization is voted by Parliament as a part of the budget of the ministry concerned.

The need for the establishment of some kind of coordinating agency has long been felt. This agency could be assigned the task of taking an overall view of the requirements of science and technology in the background of national requirements and to assign priorities in the allocation of total available funds and resources.

A number of countries have established a national science policymaking body to suit their special conditions and to meet their requirements. The role of such a body in each country is continuously changing in the light of fresh experience and the new responsibilities and functions which have to be shouldered.

There is no such central body in India at the moment though the need for such an organization has been strongly felt and repeatedly voiced. Perhaps only "subjective" factors and the vague fear of a centralized agency for allocation of funds have prevented the formation of such a body.

The science policy of a country is not just a pious statement of the aims and aspirations of the country; it also lays down the positive steps and the broad actions required to be taken in order to achieve the desired national objectives. A central agency may have to explicitly state, from time to time the long-range and short-range national objectives, specify the actions to be taken, place responsibilities, as well as identify the agencies for implementation. In the absence of such an integrating and supervisory organization the scientific policy resolution, may remain a mere expression of policy.

The Scientific Advisory Committee to the Cabinet (SACC) performs some supervisory functions. How far it covers the wide range of problems under scientific policy and how far it is effective in discharging them is generally not known, in the absence of published material on its deliberations and decisions.

The problems of planning of scientific research involve (*a*) translation of national requirements into scientific and technological projects; (*b*) establishment of priorities to different sectors of research; and (*c*) generation of necessary scientific and technological potential, in terms of organizational and institutional framework, manpower, scientific instruments and equipment to sustain these, and development research activity to meet the national objectives.

The scientific policy resolution states:

> Science has developed at an ever-increasing pace since the beginning of the century so that the gap between the advanced and backward countries has widened more and more. It is only by adopting the most vigorous measures and by putting forward our utmost efforts into the development of science that we can bridge the gap. It is an inherent obligation of a great country like India with its tradition to scholarship and original thinking and its great cultural heritage to participate fully in the march of science which is probably mankind's greatest enterprise today.

To attain the above objectives the resolution emphasized various measures to be taken such as—

(i) Promoting science in all fields;

(ii) Maintaining an adequate supply of scientific and technical manpower and research equipment for the laboratories;

(iii) To encourage individuals for discovery of new knowledge; and

(iv) In general to secure for the people of the country all the benefits that can accrue from the acquisition and application of scientific knowledge.

The Government of India decided to pursue the policies of offering "good conditions of service to the scientists and according to them an honored position by associating scientists with the formulation of policies, and by taking such other measures as may be declared from time to time."

The six major groups mentioned earlier (p. 2) are the chief national implementing agencies. They function with varying degrees of sensitivity in giving shape to the research programs and in implementing national policies such as the science policy resolution. They provide the necessary scientific and technical support for the growth of the national economy.

Tables I, II, III, and IV give certain data to indicate investment in scientific research.

The Central Government expenditure on scientific research increased from Rs46.85 million in 1950–51 to Rs121.38 million in 1955–56. The rate of growth during this period was approximately 21 percent per annum. During the second plan period it increased from Rs121.38 million in 1955–56 to Rs300.65 million in 1960–61. The rate of growth during this period was approximately 20 percent per annum. During the third plan, it increased from Rs300.65 million in 1960–61 to Rs969.61 million in 1965–66. The rate of growth during this period was 26.5 percent per annum.

An analysis of the data points to certain trends:

(i) At the beginning of the first 5-year plan, top priority was being accorded to the sector of scientific, technological, and industrial research; the second priority was for agricultural research; and the third for animal husbandry and veterinary research. At the end of the third plan, top priority has shifted to atomic energy, followed by scientific and industrial research, defense, and agricultural research in this order. It is noticed that at the end of the third plan period atomic energy research and development has absorbed more than one-third of the total Central Government expenditure on scientific research. It is a moot point to consider whether a disproportionate support to atomic energy should not be balanced by a substantial support to other areas of science also. This is a problem faced by a number of scientifically advanced countries, but is of specially added importance in the developing countries.

(ii) Of the total capital expenditures a major portion was incurred on atomic energy research and partly on CSIR and defense science; negligible amounts were spent on other scientific organizations. Hence it can definitely be concluded that for most of the research organizations other than those stated above, the research facilities in real terms per scientist have been continuously decreasing, and the direct and indirect returns are not commensurate with investment.

(iii) The science and technology in the developing economies have to be the instruments for accelerated industrial development and economic growth with limited resources. The main task before the policymakers and planners of research and development is to bridge the gap between their level and that of the advanced nations and obtain a many times higher rate of returns in terms of economic growth, from per-unit investment in research.

If it is accepted that it is necessary and possible for the developing countries to catch up with the advancements, the first task would be to plan science and technology within the framework of clearly identified areas of development in the plans of industrial and economic growth. The conception of science and technology as something abstract must be discarded and planning of research and development made an integral

part of economic growth. While in no way underestimating the non-economic returns by way of cultural advancement and satisfaction to creative minds, the sights must be kept clear in regard to the basic objective of science and technology in the developing economies. Science and technology must be in such circumstances far more closely and rigidly planned.

No developing country can have any hope of catching up, much less of becoming a leader in any single field, unless it starts from an advanced stage and develops specialist technology of its own thereafter. Transfer of technology from the advanced nations to the developing ones is one of the major planks for rapid and accelerated industrial growth and should figure prominently in the national economic and scientific policies of the developing countries. Advanced technology insures application of concentrated research, development, and experience at points of maximum return in the developing economy. Choice of technology from competing ones, economics of it, adaptation and orientation in keeping with the national resources of raw materials, and genius of the people should form the main task of science policy. It would hardly be wise or economic to make any effort to re-create technology or permit limited resources to be sued to infructuous ends, while the transfer of advanced technology would itself require a sound technological base in the recipient countries to insure speedy adaptation and assimilation and further development. Planning of scientific and technical manpower and science education are a part and parcel of science policy and equally a part of planning for economic growth.

The planning of research and development must be such as to give greater emphasis on research sensitive areas. Use of latest techniques of social research such as operational research, management techniques, systems engineering, and programing through computers must be employed to forecast the requirements of scientific and technical manpower and work out systems in the developing economy where research can be employed to give maximum returns in terms of economic growth.

(iv) In table IV the indicators chosen are: (*a*) Central Government expenditure on scientific research as percentage of total Central Government expenditure; (*b*) estimated total expenditure on scientific research as percentage of national income; and (*c*) per capita expenditure on scientific research. The trends of these indicators over the three plan periods are given in columns 4, 7, 10, and 11, respectively, of table IV. The shift in the elasticity of Central Government expenditure on scientific research is also given in column 4 of table 4.

(*a*) The Central Government expenditure on scientific research was only 0.86 percent of the total Central Government expenditure at the beginning of the first plan. The percentage of expenditure on scientific research is about 1.77 at the end of the third plan.

(*b*) The rates of growth of national income at current prices during the three plan periods were: 1, 7, and 6 percent per annum; those of total Central Government expenditure were 14, 15, and 18 percent per annum; and those of Central Government expenditure on scientific research were 21, 20, and 26.5 percent per annum.

Federal expenditure on scientific research in the United States was about 15 percent of the budget during 1963–64.

It is found that in relation to national income the proportion of total estimated expenditure on scientific research rose slightly more than 10

times during the 3 plan periods; but in relation to total Central Government expenditure during the period, it increased roughly twice.

The expenditure on scientific research was 0.06 percent of the national income at the beginning of the first plan. During the last year of each plan period it became 0.14, 0.25, and 0.59 percent, respectively.

International comparison, table V

(i) In most of the countries, nongovernmental institutions play a very important part in the promotion of scientific research. This is not the case in India. In Japan, government's share was 59 percent during 1958 and fell to 25 percent during 1963. In France also, government's share fell from 78 percent during 1958 to 50 percent during 1963. In the Federal Republic of Germany, government's share went up from 55 percent during 1959 to 64 percent during 1964. In the United Kingdom and the United States, governments' contributions were comparatively more consistent. In the United Kingdom it decreased a little from 67 percent during 1958 to 64 percent during 1963. In the United States it went up from 57 to 58 percent.

(ii) The rate of growth of expenditure on scientific research was the highest (41 percent per annum) in Japan during the period 1958–63. This was not so much due to Government's participation as to the very active part played by the private sector. The contribution of private sector has been increasing at the rate of 70 percent per annum (during 1958–61).

The next highest rate of growth (23 percent per annum) was noted in the U.S.S.R. during 1958–64. Even though the U.S.S.R. has been spending large sums it is interesting to note that she has been maintaining a steady and high rate of growth.

The rate of growth in India (17 percent per annum) is comparable to that of FDR (16 percent per annum) and France (15 percent per annum). The only difference is that India has a higher growth rate with the absolute level of expenditure being low whereas France and FDR indicate high rates and the levels also are high.

(iii) The per capita expenditure on scientific research has been calculated. India was spending roughly Rs0.67 per annum per person during 1958 and it rose to Rs1.29 during 1963. Indian figures do not compare well even with the nearest minimum figures of Japan (Rs11.5 during 1958 and Rs61.6 during 1963). In the U.S.S.R. also there was a big rise in per capita expenditure (Rs37.8 during 1958 and Rs120.4 during 1964). The highest was in the United States (Rs229.3 during 1958 and Rs320.8 during 1963) followed by the United Kingdom (Rs123.6 during 1958 and Rs174.3 in 1963).

(iv) India was spending the minimum percentage of national income for scientific research. The absolute increase in the percentage was also minimum for India during the period 1958–63. It increased from 0.21 percent during 1958 to 0.35 percent during 1963. The next minimum percentage was in Japan, but it was as high as 0.95 during 1958 and within the course of 5 years it rose to 2.5 percent, the U.S.S.R. (1.2 percent during 1959 and 2.8 percent during 1964) and Japan recorded the maximum net increases in percentage. In the United Kingdom, it was the highest throughout the period (2.6 percent during 1958 and 2.9 percent during 1963).

In both the United Kingdom and the United States the rates of growth of national income and expenditure on scientific research were reaching a point of stability. The national income in the United Kingdom and the United States increased, respectively, at the rates of 5 and 5.5 percent and

expenditure on scientific research at 8 and 9 percent per annum. Even though in these countries the expenditure on scientific research is already at a high level they continue to grow at a rate higher than the rate of increase in national income.

Some selected economic indicators are given in the appended chart (fig. I, p. 72).

Perhaps it would be inappropriate in this paper to enumerate the growths which have taken place in the economic and the social service sector during the third 5-year plan. Suffice it, however, to say that there have been laudable increases but very much remains to be done. For example, the generating capacity for power has increased from 5.6 million kilowatts to 10.2 million kilowatts, the number of schools increased from 400,000 to 500,000 of students in schools from 45 to 68 million of engineering graduates from 58,000 to 93,000, of doctors from 70,000 to 86,000 and family planning centers from 1,649 to 11,474—table VI.

The people are much better educated now than they were 15 years ago. There has been in particular a remarkable growth in technical education of personnel. Expenditure on scholarships has increased from Rs2.75 crores in 1950–51 to Rs35 crores in 1965–66 and new opportunities have been provided to students from poorer families. The people are also much more healthy. Malaria has been eradicated. The average expectation of life has increased from 32 years in the forties to 50 years today.

So far an attempt has been made to indicate (*a*) the realization by India that science and technology form a crucial element in its economic and social development and (*b*) the efforts and investment made so far for development and use of science and technology. It would be noticed that even though in absolute terms the actual percentage of investment and the increase in the rate of investment are not satisfactory yet for a country like India taking into account its meager resources and that it started from almost zero, they can be considered as feasibly creditable. There are some obvious imbalances, as for example investment in the life sciences like agriculture, investment in earth sciences and science education, and research in schools-universities, have been unsatisfactory. These imbalances are due mainly to (*a*) the unfortunate gaps in our planning and (*b*) lack of leadership and organizational ability of Indian scientists responsible for these sectors and not so much to hesitation on the part of the state in providing the necessary resources. Fortunately these imbalances are now being rapidly corrected.

The economic indicators given in table VI and figure I will indicate that steady improvements are taking place in India. It is, however, obvious that the rate of growth, especially when we take into consideration the rate of growth of population is not satisfactory. Looking at the world picture we find that one of the most important international problems today is that the rich nations are getting richer and the poor nations are getting comparatively poorer—in fact the gap is growing wider. This was eloquently expressed by a number of speakers in the seventh meeting of the panel in January 1966 and by Vice President Hubert Humphrey in his keynote address:

> * * * for the first time man possesses the power to bring mankind's benefits through science and technology to the parts of the earth that are still living in darkness and hunger. We can either rebuild and make a new world, or destroy the old one and I suggest that we build on the foundations that we have, but build anew and direct our great knowledge, our great fund of knowledge, in science and technology with a spiritual dedication that all of it has but one purpose: the emancipation of mankind from his fear; from his hunger; from his dispair; and to imbue him with faith, confidence, optimism love and hope. I believe this is what we mean when we put together public policy and science.

What is actually happening, however, is that the richer nations of the world are getting richer and the poorer nations are getting poorer.

As Lord Snow said in these meetings last year:

> * * * I don't believe that anything will stop the material progress of all advanced societies, i.e., North America, nearly all of Europe, the Soviet Union, and a few more.
>
> In short, the rich countries will get richer—I don't think there is any doubt about that, and this is where the anxiety comes in, and here I link up absolutely and completely with what the Vice President said in his introductory address. I wish I could believe that the poor countries containing more than half—I think he said two-thirds—of our fellow men would not get relatively poorer, perhaps absolutely poorer, but certainly relatively poorer. The more we look at our own scientific and technological problems, the more, perhaps, we comprehend the enormous effort that is required by societies which have not had our history and our luck.
>
> To echo with reverence the greatest of democratic leaders, the world cannot survive in peace half rich and half poor. It remains to be proved whether it can for long survive at all.
>
> I think the first thing is to realize the gross scale of the problem, which is enormous. It is not in any degree done by small-scale voluntary help. It will take enormous national effort, an effort at least as great as we are putting at the moment into, say, defense—that sort of thing—and politically, of course, it is terribly hard to persuade any population living fairly prettily that this is a right or even a reasonable thing to do.

And finally:

> How we bring about this desirable state of affairs, I really don't think anybody in the world knows. I think the first is to grant that the problem is an immense one. It isn't one that is going to take a few thousand or even millions of dollars, or a few well-intentioned technocrats or devoted engineers, doctors, and agriculturalists. It is really a problem on the scale of war. That is what I think we have got to realize. The investment seems to be of the order of many billions of dollars that make the slightest real impact on a country like India, for example.

Gerard Piel further enlarged on what Lord Snow said:

> The process of development has never been a humane one in the history of mankind. The industrial revolutions of Europe and of America consumed human beings at a cruel rate. What is going on in China today represents an extension of that historic process. The alternative which Lord Snow has developed here is that capital assistance, and assistance by way of know-how and knowledge, as the Vice President emphasized, can make it possible for developing countries to make this transition through the industrial and on into, I suppose, the cybernetic revolution without such inhumane cruelty as has characterized this historical process in the past.

The problems that face India today are truly staggering—take, for example, the rate of population growth. Dr. Roger Revelle has made a deep study of this topic and during his eloquent address last year indicated the three main serious consequences of a rapid growth of population. It has been possible to control this in some countries, as mentioned by Dr. Roger Revelle, like in Japan, Hungary, Sweden, and Italy. India is waging an almost desperate struggle to control population growth. However, as is generally realized and accepted, success in these efforts is tied up with many complicated factors, and is closely related to rapid social betterment and economic development; i.e., with rapid increase in education and of economic growth.

Besides control of population, the second major problem facing India is to increase its agricultural productivity, specially of food grains. India again is making intensive efforts to increase at least by 50 percent its agricultural production during the next 5 years. But here again, as is generally agreed, this is closely linked with (1) an enormous growth of industrial production in the fields of fertilizers and pesticides productions; (2) rapid development of engineering industries related to agriculture; (3) extensive programs for water conservation and distribution; and (4) scientific research and education in soil condition, production of better seeds, and improved methods of cultivation. Here again it is felt that success is within India's

grasp. But both these problems, i.e., population control and increased agricultural production, need not only an enormous direct investment but also indirectly a very much increased rate of investment in science and technology, scientific research, and scientific education.

There are two ways open to India for accelerating this rate of economic growth and to bridge the gap which divides the richer nations from the poorer, the two ways graphically pointed out by Gerard Piel last year. India, if it can help it, is determined to desist from following "the historic process" which is, today probably being followed by China. The alternative process of development was suggested by Lord Snow and India, therefore, is looking for international capital assistance and assistance by way of know-how and knowledge. The conference in Geneva in February 1963, called on to discuss these problems did not produce much results. Actually, it even failed to realize and define the scale of the problem and its immensity which, of course, should have been its first task. The problem is immense and would need the active participation of all scientists and technologists of good will and ability from all nations of the world. But it can be done as has been so convincingly stated in J. D. Bernel's book "World Without War." The problem is not such as can be even remotely solved by the voluntary efforts such as those mentioned by Harrison Brown last year, or the scheme of deputing scientists from the advanced countries to the developing countries as is being worked out by Blackett or as is conceived by ICSU. These are all very laudable and as a recipient country India is naturally grateful. But they are a drop in the ocean considering the immensity of the problem and while these schemes bring a justified sense of satisfaction to individuals and organizations participating in them, they suffer from an inherent danger of breeding complacency and a feeling that all that is required or could be done is being done.

Besides the active cooperation, dedication, and a crusading spirit of and by the scientists, engineers, and statesmen all over the world, in a report submitted by the author to the Prime Minister of India after the 1963 Geneva Conference, it was estimated that such an international effort required a capital investment of about $20 to $30 billion for the next 20 years. This magnitude of capital could obviously be made available only if conditions were created to persuade the nations of the world to reduce their present total armaments bill of nearly $150 billion a year. It is for the statesmen of the nations of the world to answer the question if that is possible. An Indian finds it absolutely tragic and disastrous that India is spending nearly $2 billion a year including a major portion of its foreign exchange earnings, on armaments. And, of course, the major query still remains: will the nations of the world, even if they were persuaded and convinced to cut down their expenditure on armaments, have the will and foresight and the awareness to heed the warning sounded by the late President Kennedy: "The world cannot survive in peace—half rich, half poor."

To conclude it would be appropriate to quote what Roger Revelle said last year:

> Science itself is essentially optimistic. That is why it is needed in all countries, and particularly in the developing countries—not because of the physical or mechanical things it can produce but because of its spirit of rationality and optimism; its faith that men can understand not only the world but themselves; its belief that changes in the human conditions can occur and that those changes can be guided by human beings; and its demonstration that there is a real unity of human thought, that men truly are a band of brothers.

* * *

The author wishes to express his thanks to A. Rehman for his assistance in preparing this paper and acknowledge the data drawn from two papers (i) "State Support to Research in India," Report No. 8; and (ii) "Science Policy in India," Occasional Paper Series I by A. Rehman and others.

TABLE I.—*Total expenditure on scientific research—At current price levels*

[Rupees in millions]

S. No.	Year	Current price level	1952–53 price level	Index number of wholesale price (all commodities)—Base 1952–53=100	Capital expenditure as percent of total expenditure
1	1950–51	55.75	48.48	115.0	21.23
2	1953–54	99.53	92.16	108.0	3.80
3	1955–56	144.44	156.15	92.5	6.43
4	1958–59	270.07	240.92	112.1	25.20
5	1960–61	357.77	286.45	124.9	18.00
6	1963–64	598.34	442.23	135.3	22.60
7	1964–65	832.42	545.13	152.7	32.26
8	1965–66	1153.84	695.08	166.0	44.94

TABLE II.—*Expenditure on scientific research by center and States classified according to sectors*

[Rupees in millions]

S. No.	Sector of research	Total			Percentage of grand total
		Rec.	Cap.	Total	
1	Agriculture and Forestry	83.012	3.041	86.053	11.06
2	Animal husbandry, fisheries and dairy	29.417	.885	30.302	3.90
3	Scientific, industrial, and technological research	103.678	47.044	150.722	19.38
4	Medicine and public health	51.488	.396	51.884	6.67
5	Irrigation and power	26.603	3.052	29.655	3.81
6	Geological survey	55.199		55.199	7.10
7	Atomic energy	104.128	152.728	256.856	33.03
8	Railways	9.243		9.243	1.19
9	Defense	60.850	18.544	79.394	10.21
10	Others	28.398		28.398	3.65
	Grand total	552.016	225.690	777.706	100.00

TABLE III.—*Exponential rate of growth of expenditure on scientific research and its elasticity in terms of overall growth in different sectors during the three plan periods*

Sectors	Exponential rate of growth during—			Elasticity of expenditure during—		
	1950–51 to 1955–56	1955–56 to 1960–61	1960–61 to 1965–66	1950–51 to 1955–56	1955–56 to 1960–61	1960–61 to 1965–66
1. Agriculture and Forestry	13.5	15.0	3.5	0.61	0.75	0.18
2. Animal husbandry, fisheries, and dairy	8.0	14.0	7.0	.38	.70	.37
3. CSIR	4.5	24.0	20.0	.21	1.20	1.05
4. Scientific, industrial, and technological research (including CSIR)	16.0	13.0	18.5	.76	.65	.95
5. Medicine, public health, and forensic sciences	16.0	30.0	9.5	.76	1.50	.50
6. Irrigation and power	21.0	13.0	15.0	1.00	.65	.79
7. Geological survey	13.0	29.0	20.0	.61	1.45	1.05
8. Atomic energy		34.0	20.0		1.70	1.05
9. Economics and statistics		14.0	9.0		.70	.47
10. Anthropology and archeology	13.0	10.0	2.0	.61	.50	.11
11. Railways	26.5	36.5	19.0	1.26	1.83	1.00
12. Defense	[1] 22.0	15.0	122.5 (33.5)	[1] 1.05	.75	6.45 [2] (1.76)
Overall	21.0	20.0	19.0	1.00	1.00	1.00

[1] During 1952–53 to 1955–56.

[2] During period 1961–62 to 1965–66.

TABLE IV.—*Trend of expenditure on scientific research as (i) percentage of total Central Government expenditure and (ii) as percentage of national income, and concentration coefficient of expenditure on scientific research*

Year	Total Central Government expenditure (rupees in millions)	Expenditure on scientific research by Central Government (rupees in millions)	Expenditure on scientific research as percentage of total (Central Government) expenditure	National income (rupees in abja) [1]	Estimated [2] total expenditure on scientific research (rupees in millions)	Estimated [2] total expenditure on scientific research as percentage of national income	Concentration coefficient	Population [3 4] (millions)	Per capita expenditure on scientific research	
									Current price level (rupees)	1952–53 price level (rupees)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1950–51	5,472	46,850	0.86	95.3	55.75	0.06	0.2734	350	0.16	0.14
1953–54	7,418	83,641	1.13	104.8	99.53	.10	.3208	372	.27	.25
1955–56	10,437	121,380	1.16	99.8	144.44	.14	.1963	387	.37	.40
1958–59	16,697	226,948	1.36	126.0	270.07	.21	.1977	402	.67	.60
1960–61	20,946	300,646	1.44	141.4	357.77	.25	.1783	436	.82	.66
1963–64	44,354	502,807	1.13	172.0	598.34	.35	.1693	464	1.29	.96
1964–65	43,814	699,509	1.60	[4] 179.0	832.42	.47	.2086	475	1.75	1.15
1965–66	47,977	969,609	2.02	[4] 187.0	1,153.84	.62	.2752	486	2.37	1.43

[1] An abja=Rs100 crores, i.e., Rs1000 million.

[2] Estimated: This is estimated from the estimates of grants made available, by the CSIR, ICAR, ICMR, atomic energy establishments, commodity committees of the Ministry of Food and Agriculture, Ministry of Health and various other agencies in the Central Government, to universities, for scientific research in various fields to be about 2.5 percent of the total Central Government expenditure on scientific research. This is made available to universities and various other higher technological, medical, and educational institutions in the form of research schemes, research fellowships, etc. It may not be unrealistic to assume that something equivalent to say another 3 to 5 percent or say 4 percent of the Central Government expenditure is made available by higher educational centers for research in the form of part-time availability of teaching staff, laboratory facilities like light and electricity, power, library facilities, chemicals and apparatus, common laboratory technical assistance and clerical help, stationery and facilities for printing, etc., for research activity. It is also estimated, from available data for the year 1963–64, that equivalent to 10 percent of the Central Government expenditure on scientific research is spent by the State governments for scientific research. From the industries report it is estimated that something equivalent to 4 to 6 percent or say 5 percent of Central Government expenditure on scientific research is being spent by public and private sector industries and research associations for scientific research and development. Thus, raising the Central Government expenditure on scientific research and development by a factor 1.19 is likely to give us a reasonably good estimate of the total expenditure on scientific research. The raising factor may not be same over the fast changing period in view; however, it has been assumed to be the same over the whole period, in the absence of any better criterion ("Research Efforts in Industrial Establishments in India," Survey Rept. No. 3, Survey and Planning of Scientific Research Unit, CSIR, New Delhi, 1965).

[3] Population figures have been estimated assuming that between 1960–61 and 1963–64 the rate of growth was 2.1 percent per annum and between 1963–64 and 1965–66 2.3 percent per annum.

[4] Estimated.

TABLE V.—*International comparisons*

Country	Year	Expenditure on scientific research and development (rupees in millions)			Population (in millions)	National income (in abja [1])	Gross national product (GNP) (in abja [1])	Percentage of Government contribution	Rate of growth of expenditure (at current prices) on scientific research during the period	Per capita expenditure on scientific research (rupees)	Expenditure on scientific research as percentage of—		Elasticity of expenditure in relation to national income
		Government	Others	Total							National income	Gross national product	
0	1	2	3	4	5	6	7	8	9	10	11	12	13
FDR	1958	1,592	1,327	2,919	52.1	206.05	264.86	55	16	56.0	1.4	1.1	1.45
	1964	4,584	2,578	7,162	56.1	402.01	501.92	64		127.7	1.8	1.4	
France	1958	1,692	482	2,174	44.8	183.77	238.44	78	15	48.5	1.2	.9	1.57
	1963	2,193	2,193	4,386	47.9	288.75	381.82	50		91.6	1.5	1.1	
India [2]	1958	257	13	[3] 270	402.0	126.0		95	17	.67	.21		2.61
	1963	568	30	[3] 598	463.0	172.0		95		1.29	.35		
Japan	1958	620	434	1,054	91.5	110.67	132.04	59	41	11.5	.95	.80	2.48
	[4] 1963	1,555	4,345	5,900	95.8	238.58	283.83	26		61.6	2.5	2.1	
United Kingdom	1958	4,284	2,121	6,405	51.8	246.79	306.86	67	8	123.6	2.6	2.1	1.60
	1963	6,027	3,348	9,375	53.8	317.92	401.97	64		174.3	2.9	2.3	
United States	1958	22,748	17,351	40,099	174.9	1,743.27	2,133.25	57	9	229.3	2.3	1.9	1.64
	1963	35,072	25,680	60,752	189.4	2,268.44	2,794.09	58		320.8	2.7	2.2	
U.S.S.R	1958	7,830		7,830	206.9	655.20		100	23	37.8	1.2		3.28
	1964	27,217		27,217	226.0	988.26		100		120.4	2.8		

[1] An abja=Rs.100 crores Rs.1000 millions.
[2] 1958 means for 1958–59; 1963 means for 1963–64.
Conversion rate (1962 conversion rate has been utilized for 1963 and 1964):

Foreign currency	Number of Indian rupees	
	1958	1962
Deutsche marks	1.1441	1.1943
New francs	.9744	.9345
Yen	.01324	.01328
Rubles	5.20	5.20
Dollars	4.780	4.775
Pounds	13.3931	13.3791

[3] Estimated according to note given in table 5.3 national income figures for 1963 or 1964 have been estimated on the assumption that they have grown at the rate recorded in 1958–61.
[4] 1963 expenditure on scientific research and development has been estimated assuming that the growth during 1958 to 1961 was maintained. (For private sector it has been assumed it doubled from 1961 to 1963 as otherwise figure looks fantastic.)

Sources:
(1) Camphell, Louise, "Science in Japan" Science, vol. 143, 3603, Feb. 21, 1964, pp. 776–782.
(2) French Science News, April–June 1961, No. 2, pp. 36–37.
(3) McEleheny, V. K., "West German Research Spending Plan for 1966 to 1968," Science, vol. 148, 3666, Apr. 2, 1965, pp. 59–60.
(4) OECD Observer, No. 13, December 1964, 1926.
(5) Annual Report of Advisory Council of Science Policy, United Kingdom, 1964.
(6) Science, vol. 147, 3657, Jan. 29, 1965, p. 486.
(7) Statistical Survey of Research in Japan, 1960, Bureau of Statistics, Office of the Prime Minister, Japan.
(8) U.N. Statistical Year Book, 1963.

TABLE VI.—*Expansion in selected programs under education and health*[1]

	1950–51	1960–61	1964–65	1965–66
Schools (thousands)	231.0	400.0	483.0	505.0
Students in schools (6 to 17 million numbers)	23.5	44.7	63.0	67.7
Engineering and technology degree level (intake) (thousands)	4.1	13.8	23.8	24.7
Diploma level (intake) (thousands)	5.9	25.8	46.2	49.9
Hospital beds (thousands)	113.0	186 0	229.0	240.0
Primary health centers	----------	2,800.0	4,500.0	4,800.0
Family planning centers	----------	1,649.0	7,701.0	11,474.0
Doctors (practicing) (thousands)	56.0	70.0	82.0	86.0
Nurses (practicing) (thousands)	15.0	27.0	39.0	45.0

[1] 4th 5-year plan, draft outline.

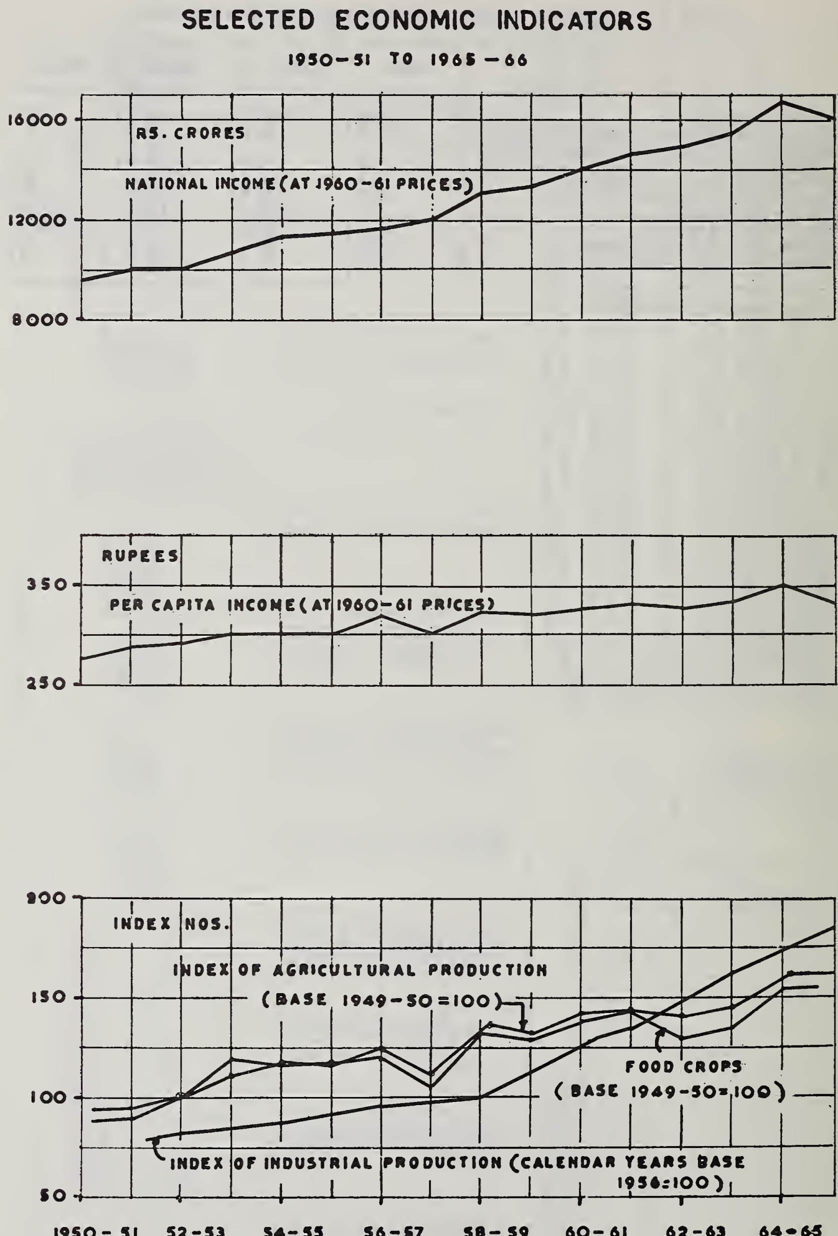
SELECTED ECONOMIC INDICATORS
1950–51 TO 1965–66
16000
12000
8000
RS. CRORES
NATIONAL INCOME (AT 1960–61 PRICES)
350
250
RUPEES
PER CAPITA INCOME (AT 1960–61 PRICES)
200
150
100
50
INDEX NOS.
INDEX OF AGRICULTURAL PRODUCTION
(BASE 1949–50 = 100)
FOOD CROPS
(BASE 1949–50 = 100)
INDEX OF INDUSTRIAL PRODUCTION (CALENDAR YEARS BASE 1956 = 100)
1950–51
52–53
54–55
56–57
58–59
60–61
62–63
64–65

FIGURE I

Appendix I

Government of India Scientific Policy Resolution

New Delhi, the 4th March 1958/13th Phalguna, 1879

No. 131/CF/57.—The key to national prosperity, apart from the spirit of the people, lies, in the modern age, in the effective combination of three factors, technology, raw materials and capital, of which the first is perhaps the most important, since the creation and adoption of new scientific techniques can, in fact, make up for a deficiency in natural resources, and reduce the demands on capital. But technology can only grow out of the study of science and its applications.

2. The dominating feature of the contemporary world is the intense cultivation of science on a large scale, and its application to meet a country's requirements. It is this, which, for the first time in man's history, has given to the common man in countries advanced in science, a standard of living and social and cultural amenities, which were once confined to a very small privileged minority of the population. Science has led to the growth and diffusion of culture to an extent never possible before. It has not only radically altered man's material environment, but, what is of still deeper significance, it has provided new tools of thought and has extended man's mental horizon. It has thus influenced even the basic values of life, and given to civilization a new vitality and a new dynamism.

3. It is only through the scientific approach and method and the use of scientific knowledge that reasonable material and cultural amenities and services can be provided for every member of the community, and it is out of a recognition of this possibility that the idea of a welfare state has grown. It is characteristic of the present world that the progress towards the practical realization of a welfare state differs widely from country to country in direct relation to the extent of industrialization and the effort and resources applied in the pursuit of science.

4. The wealth and prosperity of a nation depend on the effective utilization of its human and material resources through industrialization. The use of human material for industrialization demands its education in science and training in technical skills. Industry opens up possibilities of greater fulfillment for the individual. India's enormous resources of manpower can only become an asset in the modern world when trained and educated.

5. Science and technology can make up for deficiencies in raw materials by providing substitutes, or, indeed, by providing skills which can be exported in return for raw materials. In industrializing a country, a heavy price has to be paid in importing science and technology in the form of plant and machinery, highly paid personnel and technical consultants. An early and large scale development of science and technology in the country could therefore greatly reduce the drain on capital during the early and critical stages of industrialization.

6. Science has developed at an ever-increasing pace since the beginning of the century, so that the gap between the advanced and backward countries has widened more and more. It is only by adopting the most vigorous measures and by putting forward our utmost effort into the development of science that we can bridge the gap. It is an inherent obligation of a great country like India, with its traditions of scholarship and original thinking and its great cultural heritage, to participate fully in the march of science, which is probably mankind's greatest enterprise today.

7. The Government of India have accordingly decided that the aims of their scientific policy will be—

(i) to foster, promote, and sustain, by all appropriate means, the cultivation of science, and scientific research in all its aspects—pure, applied, and educational;

(ii) to insure an adequate supply, within the country, of research scientists of the highest quality, and to recognize their work as an important component of the strength of the nation;

(iii) to encourage, and initiate, with all possible speed, programs for the training of scientific and technical personnel, on a scale adequate to fulfill the country's needs in science and education, agriculture and industry, and defense;

(iv) to insure that the creative talent of men and women is encouraged and finds full scope in scientific activity;

(v) to encourage individual initiative for the acquisition and dissemination of knowledge, and for the discovery of new knowledge, in an atmosphere of academic freedom;

(vi) and, in general, to secure for the people of the country all the benefits that can accrue from the acquisition and application of scientific knowledge.

The Government of India have decided to pursue and accomplish these aims by offering good conditions of service to scientists and according them an honored position, by associating scientists with the formulation of policies, and by taking such other measures as may be deemed necessary from time to time.

CONCLUDING OBSERVATIONS

André de Blonay

I am not a parliamentarian, neither am I a scientist. I am afraid, therefore, that I am hardly qualified to submit observations on a debate which, for the past two days, has been conducted at such a high level.

It may be that the only justification for my appearance before you at this stage is to remind you that there still exist—not only in Latin America as pointed out by Mr. Chagas—representatives of that retrograde type of human being: the scientific illiterate.

I am unfortunately a scientific illiterate, but, by reason of my activities, first at Unesco and then at the Inter-Parliamentary Union, I have been made more and more aware of the growing role played by science and technology in today's world.

I have been led, therefore, to assess the political implications, both nationally and internationally, of science and to realize that the emergence of science as a major force in national development will impose changes in political structures and in the method of work of Parliaments, with which I am concerned.

The brief observations I am going to make will bear on the problem in which I am particularly interested: the relationship between science, Parliament and Government.

My first comment is that the US Congress is to my knowledge—and I know a great many Parliaments in all parts of the world—the only Assembly where a seminar of this type can take place providing for a free exchange of ideas and information between political leaders, on the one hand, and qualified representatives of the scientific community, both national and international, on the other.

We have had evidence here, during the past two days, that the United States is ahead of most European countries in the process required for achieving the integration of science and politics, a prerequisite for any nation which wishes to develop and to implement an integrated national science policy corresponding to the needs of its people.

If I may be allowed, I should like to express one regret. This is that parliamentarians of other countries should not have had the possibility of benefiting from a meeting such as this.

There is one exception, however, namely, my friend Dr. Vratusa, from Yugoslavia. He is the only representative from a foreign Parliament present here and it happens that, in his own Parliament, the problem of the relations between science and Government and between science and economic development is very actively discussed.

Perhaps a way may be found so that on future occasions other members of the Inter-Parliamentary Union can be allowed to take part in such a seminar as I have been privileged to do myself.

I think you would all agree that it is in the interest of both the scientific community and the Government that Parliament and parliamentarians should be better informed about the problems of science and technology.

But it is a fact that parliamentarians very often do not have access to the type of information which we have had available during the past two days. I think, therefore, it would be a very important step forward in bringing about the required integration between science and politics if in other countries also a way might be found to organize seminars similar to the present one, giving politicians a chance to enter into direct contact with scientists, both national and foreign, to discuss common problems.

I further feel that the Inter-Parliamentary Union itself, which is becoming increasingly concerned with the relationship between science and politics, may well promote, in a suitable form, at the world level, a discussion of the issues involved, which, as some of you may know, have already been studied within the regional framework of the Council of Europe.

As regards the theme of our discussion, we have been given much valuable information on how science is developed and promoted in individual countries and on its relation to the executive branch of government. But, although we were guests of a parliamentary committee, very little has been said as to the role parliamentary Assemblies should play in promoting and supervising scientific development.

This, I know, is a problem which is not topical in the United States as machinery exists to ensure regular co-operation between Parliament and the scientific community.

But I should like to say that in many other countries parliamentarians are increasingly concerned as to their inability to deal efficiently with the complex issues of science and technology in a modern society.

The causes of this inability vary from case to case and one should not generalize. But there are two factors which are often found: on the one hand, some Governments are not always keen to submit to Parliament the manifold and complex issues of scientific development and policy; on the other hand, parliamentarians, who do not have such a fine instrument as the Legislative Reference Service of the Library of Congress at their disposal, find it difficult to obtain the kind of information which they require to make wise and competent decisions on issues affecting national development in all its aspects—social, economic, political and military—with the full knowledge of the facts.

According to some people—and one hears such voices raised in Europe—the trouble is that Parliament has become obsolete, that Parliament cannot adapt itself to the requirements of the modern age. They claim that decisions today can no longer be taken by lawyers debating for long hours, that modern government requires quick action and that, in the last instance, the Executive would be better advised by a computer than by a parliamentarian.

I am sure that all present would agree that this analysis of Parliament's present difficulties as they exist in various parts of the world is fundamentally wrong. We have seen here in the United States that Parliament, as well as parliamentarians, can be made science conscious and that you do not need to be a science specialist in order to make a good political decision on a matter involving science. This I think is the key factor.

Some people say: hand Parliament over to the scientists! The reply to this is that, if this were done, the situation might become even worse than it is now as each scientist would tend to be interested chiefly in his own particular field. What is needed is not an assembly of specialists, but a body composed of men, who, being well informed, can adopt an objective and balanced approach to problems involving science and technology.

The objective, therefore, is not to hand Parliament over to scientists but instead to do everything possible so as to overcome the division which exists in many countries between the political and scientific communities, between the machinery of representative democracy and organized science.

What should and what can Parliament do in matters affecting national science policy?

This is a question of vital importance today and I believe that on its solution will depend the future strength and influence of Parliament in the life of every nation.

In this respect I should like to quote from a Unesco document which defines in a very concise way what a national science policy is:

"A Government science policy might be defined as the sum of the legislative and executive measures taken to increase, organize and use the national scientific and technical potential in order to achieve the country's development aims and enhance its position in the world."

If this definition is correct, if each country should have a national science policy of this type, then this policy will become a determining element in the life of the nation and it is essential that Parliament's role should not be limited to voting budgetary appropriations required for implementing the various elements of a national science policy. This implies that in most countries the means by which the problems involving science and its manifold implications in national life are discussed at the parliamentary level must be reconsidered.

Taking this into account, the Inter-Parliamentary Union has decided to initiate the study of a question which is naturally of concern to its members, namely, "Parliament's Role in the Elaboration and Control of National Scientific Policy".

Only a week ago a group of fifteen parliamentarians representing different regions and different types of institutions, Eastern Europe, Western Europe, America, Africa and Asia, great Powers and small Powers, advanced countries and underdeveloped countries, came together in Paris, at Unesco headquarters, and discussed for two days with Unesco specialists what general principles should be followed as regards the role of Parliament in this field.

It is very interesting to note that, in spite of ideological and political differences, it was not very difficult to reach agreement on certain basic requirements.

This shows that today many of the problems concerning the relationship between Government and Parliament are problems which exist whatever the régime in power, ideology no longer being the decisive factor. They are the problems of modern society which are not so different, whether in a democratic nation of the Western type or in a Socialist State.

The Union is only at the very beginning of its studies in this field which will be continued next spring, in Palma de Mallorca, by its Cultural Committee and which, it is hoped, will eventually lead to a plenary debate at the 56th Inter-Parliamentary Conference, due to take place in Moscow next September.

I should like, if I may, to quote from the first statement which, in conclusion of its first exchange of views, the Union's Special Committee for Liaison with Unesco adopted on the subject:

1. It is the responsibility of Parliament to promote a scientific approach to national development.

2. Parliament should play an active role and should take the initiative in defining potential and objectives of the national science policy, that is, defining the aspirations and needs of nations whose legitimate representative it is.

3. Parliaments should ensure the establishment of the governmental body and institutions required for a co-ordinated formulation and implementation of the national science policy.

4. When examining national development plans and when exercising its budgetary powers, Parliament should ensure that the national scientific activities are provided with the human, financial and material resources necessary for their full development in the service of man.

5. In view of the new character of Parliament's responsibilities in this year of science and technology, it is necessary that members of Parliament be made aware of their responsibilities and legislative assemblies determining the procedures and working methods required to fulfill them.

These are goals which have already been achieved to a large extent in the United States, but a great effort will be required to attain them elsewhere.

There was one more point on which our members meeting in Paris agreed and this was that the universal nature of science implies that every State, when formulating its science policy, must take into account the imperative requirements of international co-operation and solidarity.

I should like to relate this statement to the most illuminating paper presented this morning by Dr. Hornig. Yes, science is universal. Its language ignores national barriers. Science in an interdependent world can only develop through the free flow of talent and ideas and scientists probably form the only true international community whose members share common values and have a common understanding of their objectives in the search for truth.

It was therefore encouraging to hear that US scientists are increasingly called upon to participate in the discussion of international problems affecting peace.

The concept of world peace through world law, on which great hopes were placed in the past, has not made much progress. We now look to scientists, hoping that they will make their contribution to world peace in this great tradition of scientific humanism of which we have heard so many distinguished spokesmen in this room.

Frank J. Malina

First I would like to thank Mr. Miller, the chairman of the committee, for bringing me here on such a very interesting and pleasant occasion. Like Mr. de Blonay, I think this is a very unique experience. At least, I have not experienced anything like it abroad.

Also I would like to say how nice it is to hear American. I admire very much the guest panelists who come from countries of a different language, and nevertheless speak English so well. I do not have to inflict upon you what I call my lunar French, but can talk comfortably in my Texas-American.

My comments will be limited to two points that were originally raised by Secretary of State Dean Rusk in his keynote address. They are early

warning systems in science and technology, and the problem of the "two cultures."

I am reluctant to say the "cultural gap" after what Mr. Fulton said about the word "gap" yesterday, but I would like to make some comments on the problem.

One of the vehicles that we have on the international plane for giving early warning of new developments in science and technology is what one might call the private enterprise system of scientists and engineers, that is, international nongovernmental organizations. Dr. Hornig this morning spoke at length on the importance of ICSU, the international scientific unions, and the cooperation that exists between the basic scientists.

I am afraid today the word "scientist" is losing all significance. If I say to someone that I am not a scientist, I am an engineer, he says to me, don't you work on rockets? I say yes, I do. Then you must be a scientist.

In the field of international nongovernmental organizations, cooperation in the applied sciences and the more practical engineering fields has been on a much smaller scale than in the basic sciences up to recent times. But we now find that in the modern fields of engineering—such as aeronautics and astronautics, which are so heavily influenced by the methods of the basic sciences and in which the application of new knowledge provided by the basic sciences is taking place rapidly—international nongovernmental organizations can be as useful and effective as those in the basic sciences.

I have devoted a great deal of time to international cooperation in the field of astronautics, and I think that it has been worthwhile.

There are two organizations that I would like to mention. One is the International Astronautical Federation, of which I hope Mr. Miller will not object if I say that he, together with the Queen Mother of Greece, are in a way our patron saints.

The other one is the International Academy of Astronautics. This is a body of which a number of members are in this room. There are about 275 individual members in the world now. They are leaders in the fields of the basic, engineering, and life sciences of astronautics, and this body is, I believe, valuable for giving an early warning of new developments.

I will give you two or three examples of what the academy is doing. We have a committee studying the preparation of an international meeting on the question of communication with extraterrestrial intelligence. This I think can be considered "far out," and whether early warnings will come from these considerations I cannot predict. But I can tell you that in the U.S.S.R. people are most fascinated by this question. In the academy we are looking into this matter and the International Astronomical Union has kindly said to us, go ahead.

The second one is concerned with "space" relativity. We have a committee which is considering how developments in space technology and exploration might be used for the verification of the general theory of relativity.

The third is one that I initiated. It is called the LIL project. It is a project to study the possible creation of a manned lunar international laboratory. When I proposed this at Stockholm in 1960 many of the Academicians said such a study was premature. But within 6 months Gagarin orbited the earth and President Kennedy announced the Apollo program. The project which I thought might come into fruition in about 25 years, and with which I thought I could leisurely putter around for the rest of my life, became a project of immediate interest, and it was no longer an early warning but approaching reality.

In connection with the LIL project, we have been bringing together scientists and engineers from various countries and we have been especially trying to draw into this kind of work people from outside of the United States. And I think we have had very good success.

We had at our first symposium on research in the geosciences and astronomy, at Athens in 1965, four contributions from the Soviet Union, two from France, and one each from the German Federal Republic and Poland. Last year in Madrid, in the field of life sciences and lunar medicine, we had one contribution each from England, France, Italy, Sweden, and the Soviet Union. Our next symposium will be in Belgrade next September on the subject of research in the field of physics and chemistry in a manned laboratory on the moon. In these meetings we talk about the kind of research that might be uniquely carried out on the moon.

I do not remember who made the statement—perhaps it was Dr. Hornig—that all international cooperation is finally paid for by the Government. Well, I know that in international nongovernmental organizations there are many individual contributions. Most of the engineers and scientists who do this work do not get paid for it.

Furthermore, it is possible for people from countries that do not have an advanced status in the field of astronautics to come and hear about new developments at our international meetings. I sent a paper the other day to an engineering journal in Bombay. I had been asked to write something about the future of space exploration. I concluded that, in my opinion, the exploration and peaceful uses of outer space should not be regarded as a monopoly of a small number of favored nations, but rather as a new human activity that opens opportunities to men of talent and imagination from any part of our earth.

I hope that our Government will continue to look with favor on nongovernmental international activities, and especially in the fields of the applied sciences or engineering; for the organizations in these fields are today still treated as stepsisters of the better known international scientific unions of ICSU.

Now I would like to make a few comments on the problem of the "two cultures" in our society.

While I was drawing together my thoughts on this problem I heard Mr. Davis and Dr. Chagas speak on important aspects of it. I also believe it is a real problem, in spite of the fact that some feel that it has been exaggerated by Lord Snow, who is widely known for his discussions of it.

Secretary Dean Rusk called it the gap between science and the humanities. In this context the term humanities would include the arts, but not the social sciences. In reading the proceedings of your seventh meeting last year I noted that you discussed at considerable length the relationships between the natural and social sciences, and the ways of supporting research in the social sciences.

Personally, I believe that the description of some human activities as the "humanities" (at Caltech, for example, there is a Division of the Humanities) is no longer satisfactory. One can easily be led to conclude that the sciences belong to the division of the "inhumanities," and I am afraid that this is rather common conclusion in both technologically developed and developing countries:

In the present state of evolution of society it is, therefore, terribly important to overcome the barrier of ignorance that exists between the sciences and the humanities. I agree with Dr. Chagas and Mr. Davis that too

many people do not understand the objectives, possibilities, and limitations of the basic and applied sciences. This is a serious matter, for the humanities play a great role in forming public opinion.

My experience in the field of the visual arts, which has mainly consisted of attempting to introduce the new visions provided by science, and of utilizing new technological developments as artistic media in the fine arts, has shown me that artists are either antagonistic to science or naively imitate it.

In conclusion I would like to suggest to the committee that it give consideration to devoting one of the meetings with its Panel on Science and Technology to the theme: Government, Science, and the Humanities.

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